USGS-NPS Vegetation Mapping Program: Walnut Canyon National Monument, Arizona, Vegetation Classification and Distribution

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U.S. GEOLOGICAL SURVEY
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Final Report

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USGS-NPS National Vegetation Mapping Program

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LIST OF ABBREVIATIONS AND TERMS

AA	Accuracy Assessment
ABI	Association for Biodiversity Information (now known as NatureServe)
AML	Arc Macro Language
BOR	Bureau of Reclamation (Also USBR)
BRD	Biological Resource Discipline of the USGS
CBI	Center for Biological Informatics of the USGS/BRD
CIR	Color Infra-Red photography
CPRS	Colorado Plateau Research Station of the USGS/BRD
DEM	Digital Elevation Model
DLG	Digital Line Graph
DOQQ	Digital Orthophoto Quarter Quad(s)
DRG	Digital Raster Graphic
FGDC	Federal Geographic Data Committee
GIS	Geographic Information System(s)
GPS	Global Positioning System
MMU	Minimum mapping unit
NAD	North American Datum
NBII	National Biological Information Infrastructure
NPS	National Park Service
NRCS	Natural Resources Conservation Service
NVC	National Vegetation Classification
NVCS	National Vegetation Classification Standard
PLGR	Precision Lightweight GPS Receiver
RSGIG	Remote Sensing and Geographic Information Group of the Bureau of Reclamation
SBSC	Southwest Biological Science Center of the USGS
TES	Terrestrial Ecosystem Survey
TNC	The Nature Conservancy
USBR	United States Bureau of Reclamation
USDA-FS	United States Dept. of Agriculture – Forest Service
USDA-SCS	United States Dept. of Agriculture – Soil Conservation Service
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
WACA	Walnut Canyon National Monument
VMP	Vegetation Mapping Program

SUMMARY

Walnut Canyon National Monument (WACA) Vegetation Mapping Project was initiated in the spring of 1999 as part of and in accordance with the U.S. Geological Survey/National Park Service (USGS-NPS) Vegetation Mapping Program, and was completed in the spring of 2004. The Vegetation Mapping Program is a cooperative effort administered by the USGS and the NPS, and was initiated as part of the NPS Inventory & Monitoring Program. The primary goal of the Vegetation Mapping Program is to classify, describe, and map vegetation for approximately 270 NPS units.

This mapping project was performed by the following organizations under contract to the CBI:

- The Remote Sensing and GIS Group (RSGIG), Technical Service Center, Bureau of Reclamation (BOR), Department of Interior, Denver, Colorado

- The Colorado Plateau Research Station (CPRS), Southwest Biological Science Center (SBSC), USGS, Flagstaff, Arizona

- NatureServe, Boulder, Colorado

Thirteen vegetation map classes, three land cover map classes, and eight Anderson Level II land-use map classes were used for interpretation of approximately 20,700 ac (6,900 ha), encompassing the Monument (~3,600 ac/1,500 ha) and surrounding environs (~17,100 ac/8,400 ha). Vegetation map classes were determined through extensive field reconnaissance, data collection, and analysis in accordance with the National Vegetation Classification (NVC). The vegetation map was created from 1996 1:12,000 scale color infrared aerial photographs (0.5 hectare minimum mapping unit). All vegetation and land-use information was then transferred to a GIS database using the latest grayscale USGS digital orthophoto quarter-quads (DOQQs) as the base map and a combination of on-screen digitizing and scanning techniques. Overall thematic map accuracy for the entire mapping effort was assessed at 69.2% using the acceptable error criteria with a Kappa Index of 66.7%. The overall 90% confidence interval is 64.1% to 71.8%.

Final products are presented in this report and on the accompanying CD-ROM (Appendix A).

- Vegetation Classification Descriptions
- Land-use Classification System
- Vegetation Classification Key
- Digital and Hard Copy Vegetation Map
- Digital Project Boundaries
- Digital Field Points Coverage (Observation, Classification, Accuracy Assessment)
- Photos of Field Sites
- Accuracy Assessment Results
- Federal Geographic Data Committee (FGDC)-compliant Metadata

WACA and similar National Park vegetation mapping databases can be accessed at the USGS-NPS website: http://biology.usgs.gov/npsveg.

1. INTRODUCTION

The Vegetation Mapping component of the NPS Inventory and Monitoring Program is a cooperative effort by the U.S. Geological Survey (USGS) and the National Park Service (NPS) to classify, describe, and map vegetation communities in more than 270 national park units across the United States. The vegetation mapping efforts are an important part of the NPS Inventory and Monitoring Program, a long-term effort to develop baseline data for all national park units that have a natural resource component. Project activities are based on peer-reviewed, objective science. Comprehensive vegetation information is provided at national and regional levels, while also serving local management needs of individual parks. Stringent quality control procedures ensure that products are accurate and consistent for initial inventory purposes and replicable for monitoring purposes. The spatially enabled digital products produced by these efforts are available on the World Wide Web (http://biology.usgs.gov/npsveg).

The goals of these vegetation mapping projects are to provide comprehensive mapping of NPS vegetation resources that:

1. Is highly accurate
2. Meets scientific and FGDC standards
3. Has a nationally consistent, hierarchical, classification scheme
4. Has a level of detail useful to park management
5. Uses existing data when appropriate

Efforts to support the success of the WACA vegetation mapping project led to various work contracts with the following federal government agencies and private organizations:

The Remote Sensing and Geographic Information Group (RSGIG), United States Bureau of Reclamation (USBR), Denver Federal Center, Lakewood, Colorado[1]: 1) attended planning meetings, 2) conducted aerial photosignature field review and observation point data collection, 3) provided aerial photointerpretation, 4) attended a vegetation classification map class development meeting, 5) created the GIS vegetation database and 6) provided support and content for the final report.

The Southwest Biological Science Center (SBSC), Colorado Plateau Research Station (CPRS), USGS-BRD, Flagstaff, Arizona[2]: 1) attended planning meetings, 2) conducted field data collection and analysis, 3) provided data analysis and classification, 4) prepared the vegetation

[1] The Remote Sensing and Geographic Information Group, organized in 1975, provides assistance and advice regarding the application of remote sensing and geographic information systems (GIS) technologies to meet the spatial information needs of the Bureau of Reclamation and other government clients. The mission of the Department of Interior's Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

[2] The Colorado Plateau Research Station is one of four research stations within the Southwest Biological Science Center. This research station was originally established in 1989 as a National Park Service Cooperative Park Studies Unit at Northern Arizona University in Flagstaff and was merged into the USGS Biological Resources Discipline in 1996. Major categories of research include ecoregional studies and conservation planning; endangered species studies; vegetation distribution, ecology, and dynamics; data management and dissemination; inventory and monitoring studies; and wildlife ecology.

classification key and descriptions, 5) provided accuracy assessment data collection and analysis, 6) conducted the vegetation map accuracy assessment, and 7) prepared the final project report.

NatureServe's Western Regional Office in Boulder, Colorado[3] provided a review of CPRS vegetation data analyses and CPRS local vegetation descriptions as well as prepared global descriptions for the vegetation associations determined at WACA.

[3] NatureServe has its roots in The Nature Conservancy (TNC), which in 1974 began establishing and supporting state natural heritage programs. By 1994, the natural heritage programs expanded significantly and The Nature Conservancy established a new network, the Association for Biodiversity Information. Now known as NatureServe, it has assumed in managing the National Vegetation Classification (NVC) and providing scientific and technical support to the network. The NatureServe network now includes 74 independent natural heritage programs and conservation data centers across the Western Hemisphere.

2. VEGETATION MAPPING PROJECT AREA

WACA was first designated as a National Monument in 1915 as a presidential proclamation to protect significant cultural artifacts preserved as cliff dwellings. Since establishment, WACA's boundary has expanded four times to today's size of approximately 3,600 ac (1,500 ha) and is currently being sought out for further expansion by a local advocacy group, Friends of Walnut Canyon. WACA is located approximately 7.5 mi (12 km) east of Flagstaff, AZ (Figure 1). The Monument lies adjacent to the Coconino National Forest, the city limits of Flagstaff, AZ, and Arizona State lands (Figure 2). In the eastern section of the National Monument boundary, a private in holding of 290 ac (120 ha) occurs near the Santa Fe Dam. This project also encompasses a one-mile environ around the Monument, an additional ~17,100 ac (6,900 ha) of total mapped lands.

The National Monument is visited mostly for its extensive remains of cliff dwellings once inhabited by the Sinagua people from A.D. 1000-A.D.1250. Contemporary Native American tribes continue to have significant ties to the landscape. The National Monument also acts to preserve unique biotic communities of locally rare mesic plant communities, ecotonal communities ranging from semi-arid grasslands to mesic forests, and diverse animal communities.

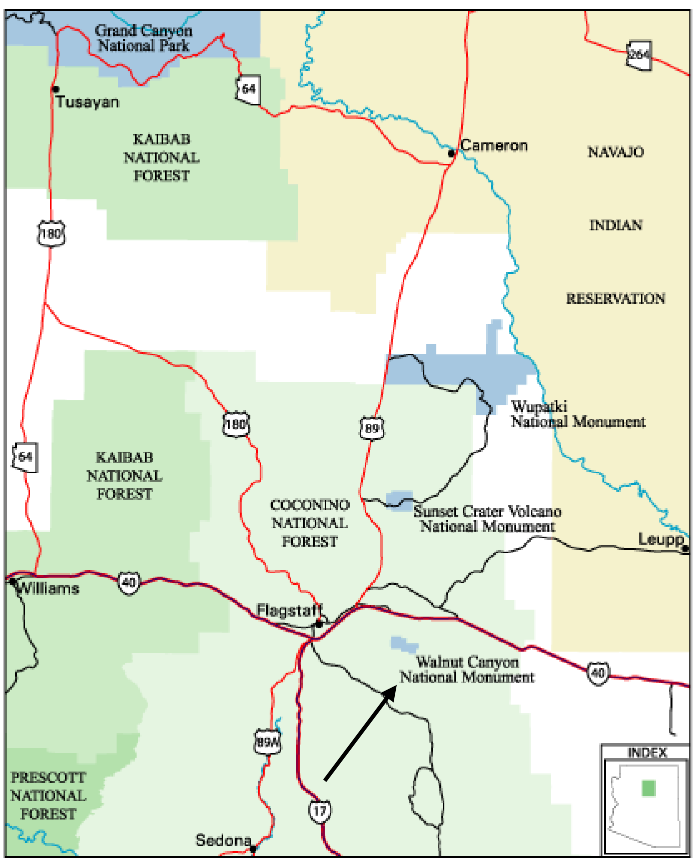

Figure 1. Location of Walnut Canyon National Monument.

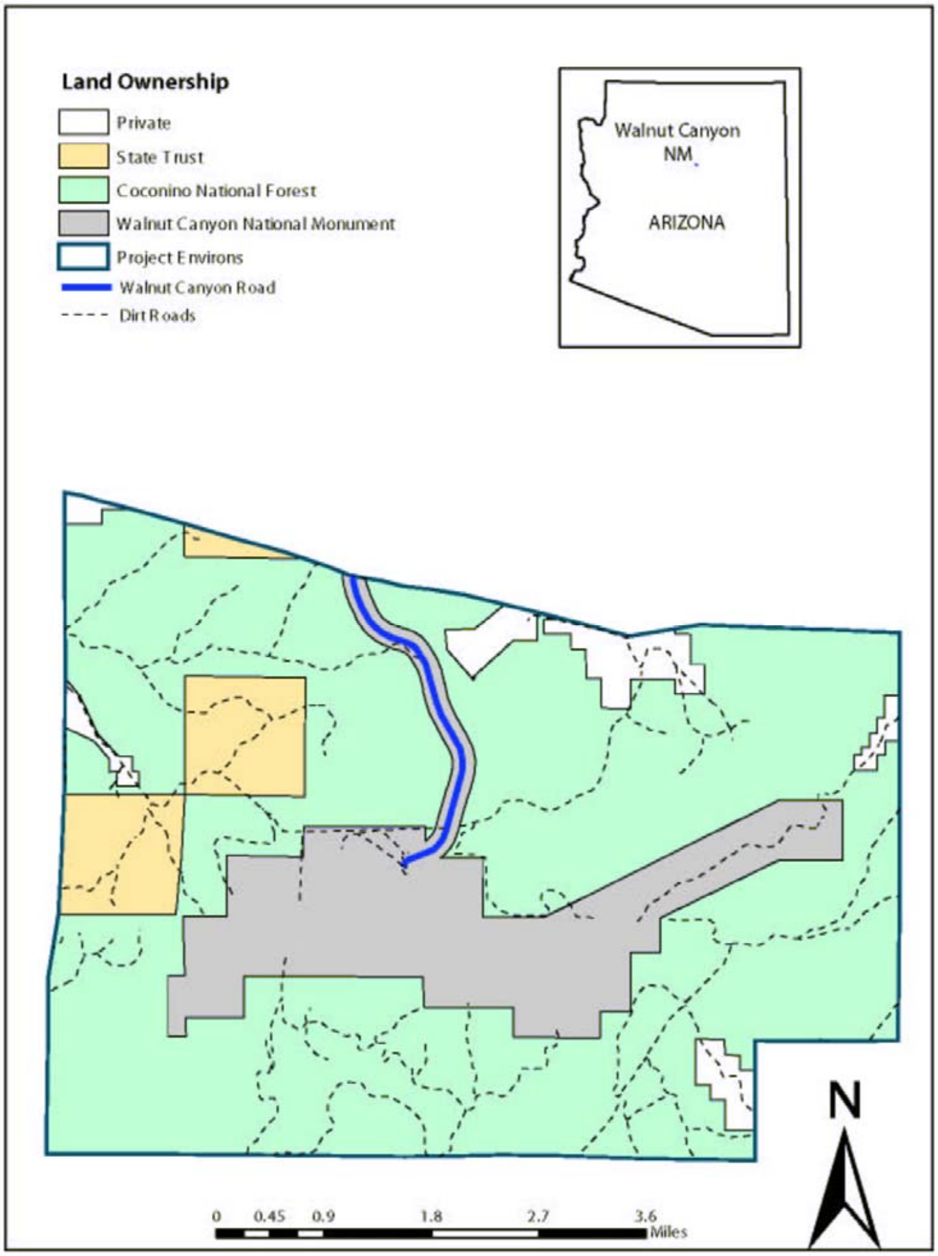

Figure 2. WACA vegetation map project boundaries and land ownership.

Location and regional setting

WACA is located on the Colorado Plateau in northern Arizona. Access to the park can be reached on a paved road, referred to as the park road in this report, to the northern rim of Walnut Canyon via Interstate-40. The main access route to the south rim of Walnut Canyon via Interstate-40 is Cosnino road, east of the park road. Cosnino road exits Interstate-40 northeast of the project boundary and winds around the southern boundary of WACA. Various other U. S.

Dept. of Agriculture - Forest Service (USDA-FS) dirt roads allow access to many other areas of WACA through the adjacent Coconino National Forest. A visitor center is maintained on the northern rim of the canyon at the end of the park road. Only two hiking trails are managed and maintained by WACA: the Island and Rim Trails. The National Monument limits public use of any area except these two designated trails and adjacent picnic areas. In the Coconino National Forest lands surrounding WACA, recreational hiking occurs throughout the project area on un-maintained trails as well as on the newly developed Arizona trail.

Climate

WACA has a semi-arid, continental climate typified by a moderately hot and moist summer, cool and dry spring and fall, and cold, periodically wet, winter. Monsoon-like precipitation events, often in the form of violent thunderstorms, occur principally from July through September. On average from 1971-2000, 5.9 in (15 cm) of rain fell from July-September out of the total 15.8 in (40 cm) of total precipitation (NOAA 2002). Average summer maximum temperatures range from 45 to 91 degrees F (7 to 33 degrees C), while average winter minimum temperatures range from 21 to 57 degrees F (-6 to 14 degrees C) (NOAA 2002). Winter snowfall average ranges from 2.5 to 4 in (6.4 to 10 cm) a month (NOAA 2002). Strong to moderate winds are commonplace within the region.

Geology, hydrology, and topography

The major geologic and topographic feature of WACA is the canyon itself (Walnut Canyon), an entrenched segment of Walnut Creek whose walls rise 300 ft (91 m) above the narrow canyon floor (Figure 3). The canyon cuts through the southeastern Coconino Plateau, a broad uplift that extends from the South Rim of the Grand Canyon to Flagstaff. Rising above the Coconino Plateau, south of Walnut Canyon in the southwestern section of the WACA project area, is an uplifted mesa referred to as Anderson Mesa. Cherry Canyon is the second largest canyon in the project area and is a major side canyon to the southeast of Walnut Canyon.

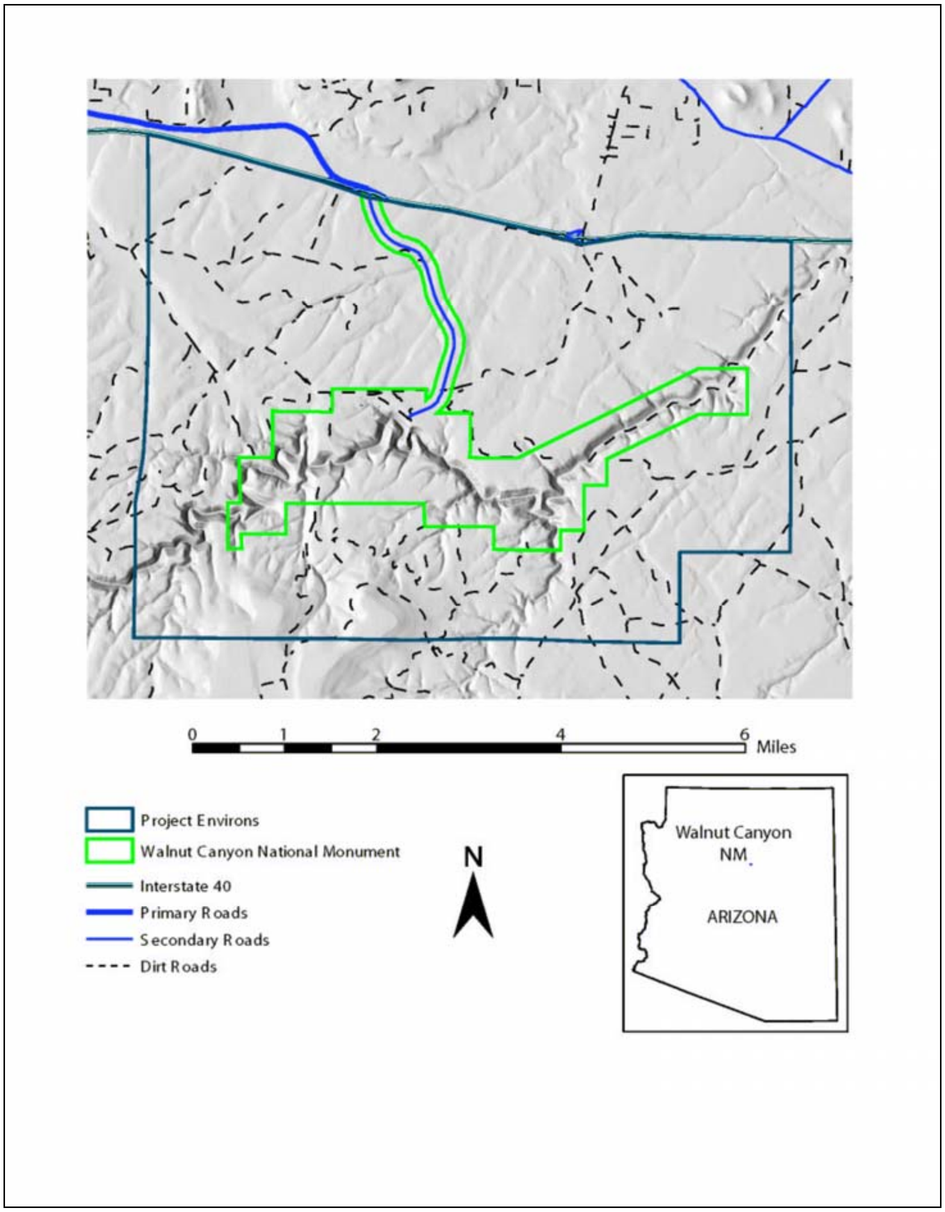

Figure 3. Shaded relief map of the WACA vegetation map project area.

In this report we refer to major landforms within the WACA project area. The main east-west canyon is Walnut Canyon. Side canyons feed into Walnut Canyon from the north and the south. The canyon consists of the canyon rims (upper lip of the canyon wall), canyon walls (slopes of the canyon), canyon terraces (level to gently sloping shelves bisecting the canyon wall), and the canyon bottom, where an intermittent drainage channel exists and water periodically scours the canyon bottom (Figure 4). The elevation in the project area ranges from 1,889m (6,197ft) to 2,207m (7,241ft). Although the vertical relief in the project area is less than 400m (~1,050ft), the vegetation responds significantly to this elevation change. We refer to elevation ranges throughout this report as low elevation (~2,000-2,100m; 6,550-6890ft), mid-elevation (the broad ecotonal area between the low and high elevation areas, ~2,100-2,200m; 6,890-7,220ft), and high elevation (~2200-2240m; 7,220 -7,350ft).

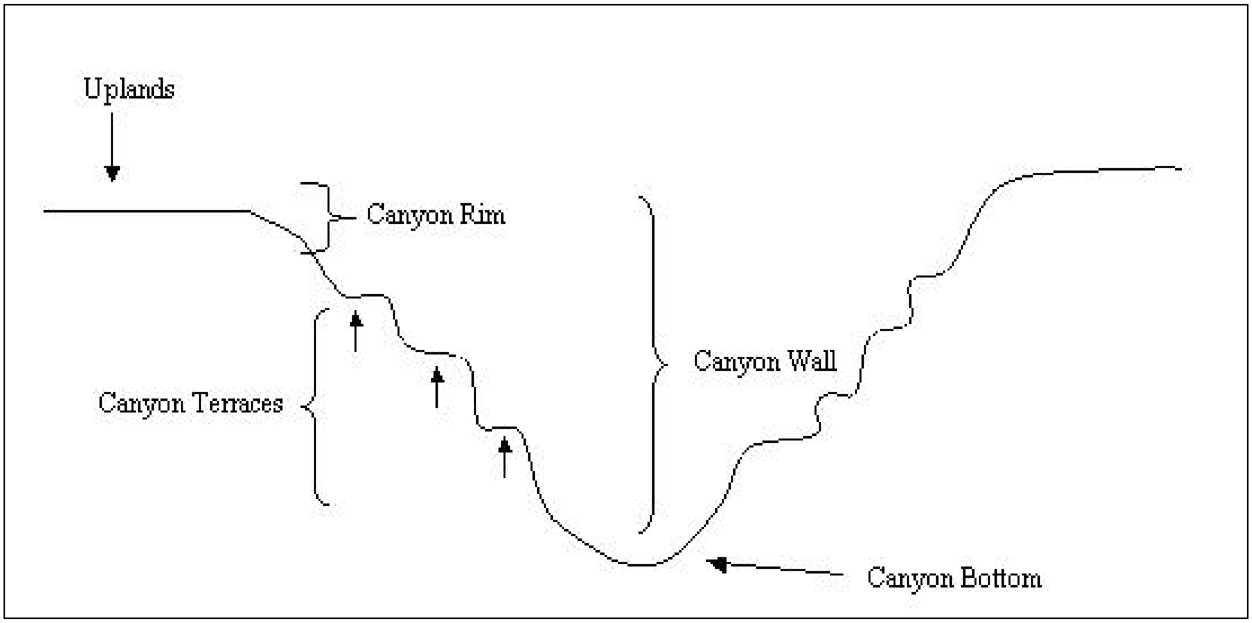

Figure 4. Landform descriptors used for the WACA vegetation map.

Well exposed within the Monument are two major rock units; the Kaibab Formation and the Coconino Sandstone (Figure 5). These units formed during the Paleozoic Era and record a time hundreds of millions of years ago when an ancient sea periodically covered much of the region (Chronic 1988).

The upper walls of Walnut Canyon are comprised of the Kaibab Formation, a resistant gray limestone that caps not only the canyon but also the rims of the Grand Canyon to the northwest. It forms characteristic ledges and slopes, and includes massive layers of limestone and dolomite as well as some thin siltstones and sandstones. Many of the layers are fossiliferous, bearing small clams, snails, and brachiopods (Chronic 1988). This unit also caps the higher, relatively flat mesas surrounding the narrow canyon within the Monument. More recent Mesozoic and Cenozoic rocks, such as the Chinle Formation seen in the Painted Desert and at Petrified Forest National Park, have been eroded away as this portion of the Colorado Plateau has risen slowly over time. Southward, the Colorado Plateau ends abruptly along the Mogollon Rim, a roughly 200 mi (320 km) long faulted escarpment that cuts across much of central Arizona.

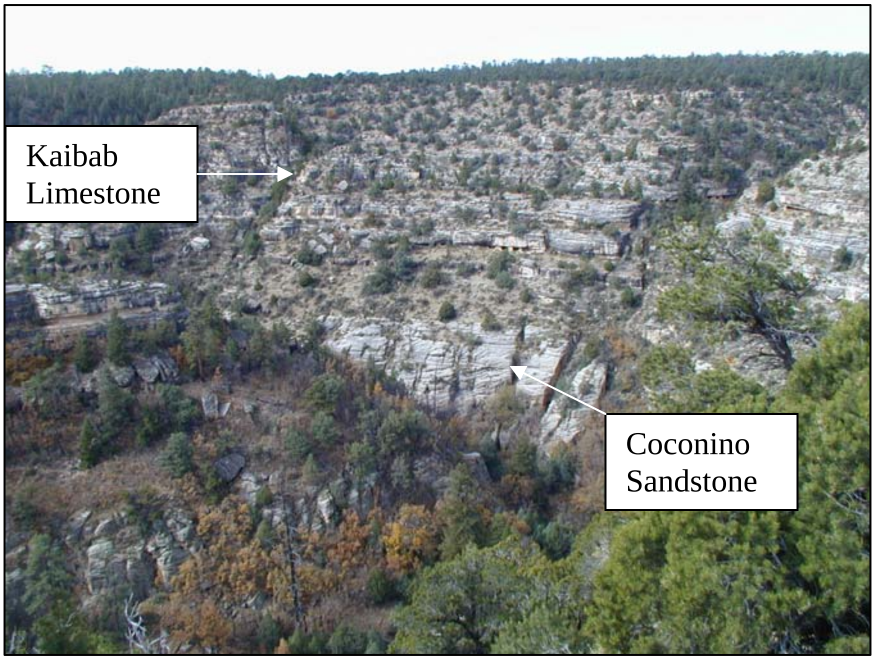

Figure 5. The two main geologic formations at WACA.

Lying stratigraphically beneath the Kaibab Formation are the light tan cliffs of the Coconino Sandstone. This distinctive unit is comprised of cross-bedded sandstones that developed as a regressive sea laid bare vast tracts of sand that were later reworked into large dune fields. Evidence of these dunes has been preserved as the striking bedding patterns seen in the rock. Much later in time faulting "broke up" these massive sedimentary units, forming small joints in the rocks that have commonly served as erosion channels. These small faults and joints likely influenced development of the canyon as these areas of fractured rock are much more easily eroded. Presumably beneath the Coconino Sandstone are additional Paleozoic rock units, such as those seen in the Grand Canyon, but the small watershed of the creek has not yet cut down into these older units.

In the southwestern section of the project area on Anderson Mesa younger basaltic soils lie on the surface of the Mesa as a result of geologically recent eruptions of Mormon Mountain.

Today Walnut Canyon is an intermittent drainage channel, but it likely flowed more often approximately 800 hundred years ago during habitation by the Sinagua, who built homes in recesses and alcoves in the canyon walls (Chronic 1988). Perennial pools may have developed, as the steep canyon walls and riparian vegetation offered shade and the scoured bedrock created small depressions that could trap water. Today Walnut Creek's upper watershed has been dammed to provide water for the city of Flagstaff. Upper and Lower Lake Mary (completed in 1903 and 1941 respectively), situated in a faulted graben south of Anderson Mesa, now capture a significant portion of the creek's water volume and this likely results in less flow through the canyon within the Monument. Prior to the dam, periodic flooding scoured the vegetation on the canyon bottom after snowmelts and summer monsoon storms.

Wildlife

Information used to prepare this wildlife summary for WACA includes Anonymous (1992), Hoffmeister (1986), Nowak et al. (2003), and Solomonson (1973), as well as additional data gathered during inventory projects for mammals and herpetofauna currently being conducted by researchers at the USGS CPRS.

Particularly in light of its proximity to suburban development, the variety of large mammals at WACA is remarkable. Mountain lions (*Puma concolor*), and occasional black bears (*Ursus americanus*) prowl the canyon and surrounding forest, and elk (*Cervus elaphus*) and mule deer (*Odocoileus hemionus*) are common. Collared peccaries (javelina; *Pecari tajacu*) are common, and are noteworthy because this is near the northern edge of their range. Among smaller mammals, Abert's or tassel-eared squirrels (*Sciurus abertii*) and gray-collared chipmunks (*Tamias cinereicollis*) are most likely to be seen because of their diurnal habits. Other mostly nocturnal small and medium-sized mammals include little brown myotis (a bat, *Myotis lucifugus*) and big brown bat (*Eptesicus fuscus*); deer mouse, brush mouse, and pinyon mouse (*Peromyscus maniculatus*, *P. boylii*, and *P. truei*); Stephens' woodrat (*Neotoma stephensi*), porcupine (*Erethizon dorsatum*), ringtail (*Bassariscus astutus*), hog-nosed skunk (*Conepatus mesoleucus*), gray fox (*Urocyon cinereoargenteus*), and bobcat (*Lynx rufus*). There are also some domestic large mammals in the eastern section of the Monument, since it is currently not fenced and open to cattle grazing, mostly in the bottom of Walnut Canyon. Cattle also graze on adjacent United States Department of Agriculture – Forest Service (USDA-FS) and State lands.

WACA supports a wide variety of birds of prey, including such rare or special interest species as Bald Eagle (*Haliaeetus leucocephalus*; in winter), Golden Eagle (*Aquila chrysaetos*), Northern Goshawk (*Accipiter gentilis*), Peregrine Falcon (*Falco peregrinus*), and Mexican Spotted Owl (*Strix occidentalis*). Other birds of prey at the Monument include Turkey Vulture (*Cathartes aura*), Sharp-shinned Hawk (*Accipiter striatus*), Cooper's Hawk (*A. cooperii*), Red-tailed Hawk (*Buteo jamaicensis*), American Kestrel (*Falco sparverius*) and Great Horned Owl (*Bubo virginianus*). Other medium-sized and large birds that inhabit the Monument are Wild Turkey (*Meleagris gallopavo*), Band-tailed Pigeon (*Columba fasciata*), and the ubiquitous Common Raven (*Corvus corax*). Smaller birds characteristic of the coniferous forest and canyon habitats of Walnut Canyon include Lewis' Woodpecker (*Melanerpes lewis*), Pinyon Jay (*Gymnorhinus cyanocephalus*), Steller's Jay (*Cyanocitta stelleri*), Pygmy Nuthatch (*Sitta pygmaea*), Black-throated Gray Warbler (*Dendroica nigrescens*), Grace's Warbler (*Dendroica graciae*), and Red-faced Warbler (*Cardellina rubrifrons*). Other common small birds are Mourning Dove (*Zenaida macroura*), Northern Flicker (*Colaptes auratus*), Hairy Woodpecker (*Picoides villosus*), Western Wood-pewee (*Contopus sordidulus*), Ash-throated Flycatcher (*Myiarchus cinerascens*), Violet-green Swallow (*Tachycineta thalassina*), Mountain Chickadee (*Poecile gambeli*), Rock Wren (*Salpinctes obsoletus*), and Canyon Wren (*Catherpes mexicanus*).

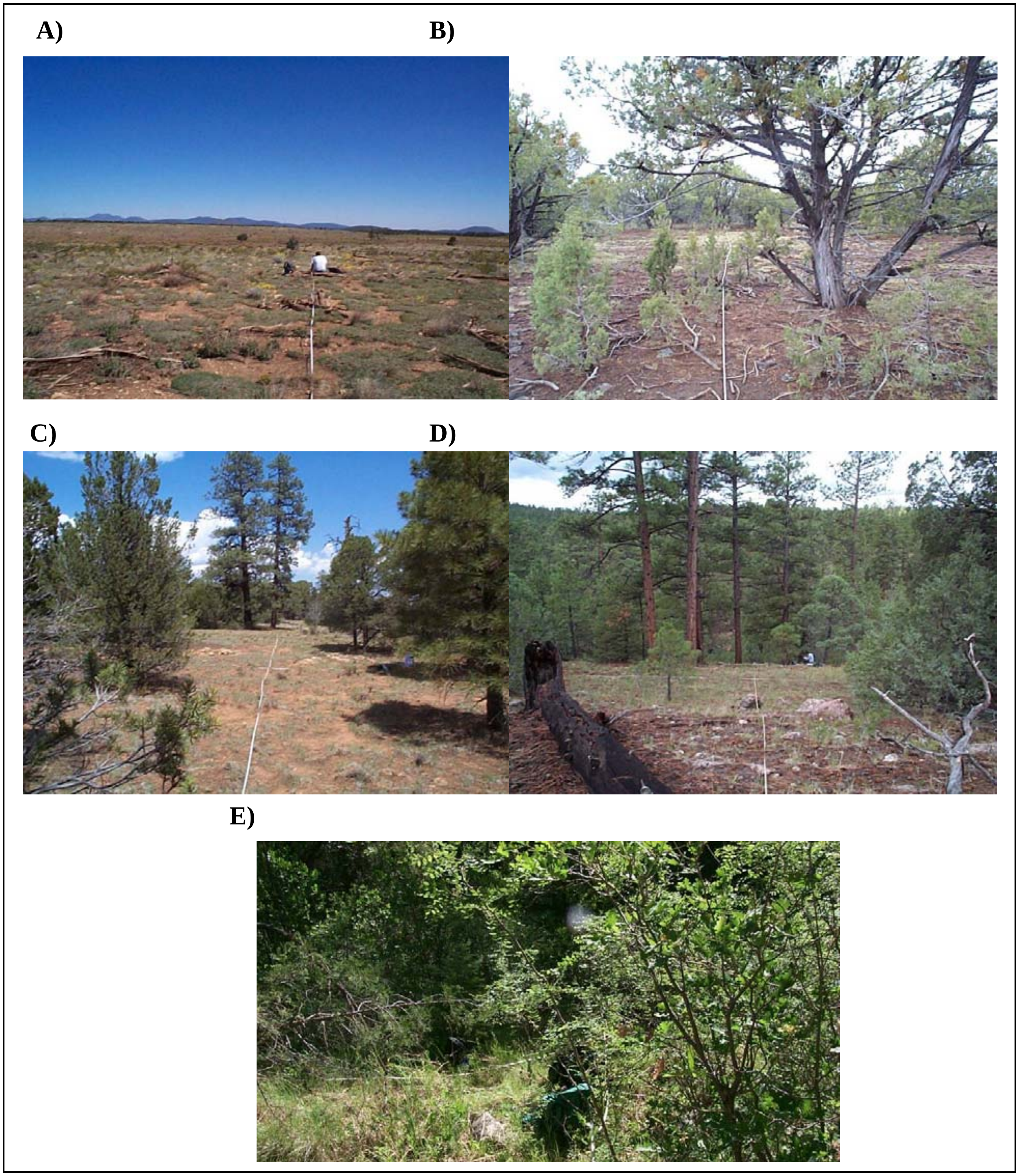

Figure 6. Vegetation typical of WACA include A) Previously chained areas with prairie dog towns, B) Utah juniper low elevation areas, C) Mixed ponderosa pine/ pinyon pine/ Utah juniper ecotonal areas, D) Ponderosa pine/ Douglas-fir mesic north-facing slopes, and E) Mesic dense riparian canyon bottom vegetation.

Amphibians are rarely encountered at WACA because of the general scarcity of surface water. Canyon treefrogs (*Hyla arenicolor*) and New Mexico spadefoot toads (*Spea multiplicata*) have been recorded from the canyon bottom and around artificial water impoundments. Among reptiles, there are several common lizard species. Eastern fence lizards (*Sceloporus undulatus*) and tree lizards (*Urosaurus ornatus*) are abundant in rocky and cliff habitats throughout the area, and the greater short-horned lizard (*Phrynosoma hernandesi*) is fairly common. The little striped whiptail (*Cnemidophorus inornatus*), and the plateau striped whiptail (*C. velox*) are both fairly common in the canyon bottom area, but are not found on the rims. Of the snakes that are known to occur in the Monument, the brightly-colored Sonoran mountain kingsnake (*Lampropeltis pyromelana*) is easily the most distinctive. The gopher snake (*Pituophis catenifer*) and the western terrestrial garter snake (*Thamnophis elegans*) are also fairly common throughout the Monument. The western rattlesnake (*Crotalus viridis*) is the only venomous snake that occurs at WACA.

Vegetation

Vegetation of WACA and the environs is diverse and ecotonal in nature (Figure 6). It ranges from low elevation grasslands to high elevation woodland and forest communities. Species that are often specific to a vegetation community more frequently intermix in WACA than other areas on the Colorado Plateau, forming a broad transition zone. Species that often co-dominate in the same habitat are pinyon pine (*Pinus edulis*), Gambel oak (*Quercus gambelii*), Utah juniper (*Juniperus osteosperma*), and ponderosa pine (*Pinus ponderosa*). High elevation species, riparian obligates, and more mesic species occur in high abundance in WACA due to north facing slopes and mesic canyon walls and canyon bottoms. These mesic and cooler environments have species that are typically found at higher elevation such as dense patches of Rocky Mountain juniper (*Juniperus scopulorum*), Douglas-fir (*Pseudotsuga menziesii*), and New Mexican locust (*Robinia neomexicana*). The canyon floor has a rich vegetation community with the overstory composed mainly of deciduous trees and shrubs, primarily box elder (*Acer negundo*), dogwood (*Cornus stolonifera*), New Mexican olive (*Forestiera pubescens*), Arizona walnut *(Juglans major*), New Mexican locust (*Robinia neomexicana*), Arizona rose *(Rosa arizonica*), and snowberry (*Symphoricarpos rotundifolius*).

Approximately 90 ac (36 ha) (<1%) of the mapping area consists of sparsely vegetated steep canyon walls or intermittent stream channels. On the canyon walls the two main geologic formations (Kaibab Formation and Coconino Sandstone) often occur in large rock outcrops on the steep slopes of Walnut Canyon with sparse to no vegetation. Hanging garden species can occur on the steep vertical canyon walls, especially in areas of water seepage. Hanging garden communities were excluded in our sampling design, since they only occurred in small patches and were difficult to sample. On the canyon bottom of Walnut Canyon and in the side canyons, intermediate stream flow can limit vegetation growth by scouring the vegetation. Prior to damming, the vegetation was much sparser in Walnut Canyon due to higher stream flow (Brian 1992). The sparse vegetation that often persists in the intermittent stream channel can consist of disturbance thriving forbs (annuals and perennials) and grasses.

Disturbance-thriving species occur in unique communities of grassland, shrubland, and steppe types in the northeastern section of WACA. The vegetation in this area was chained to increase the forage potential of the area. Gunnison's prairie dog (*Cynomys gunnisoni*) colonies also thrive in this area. The results of these activities are a recently disturbed, diverse community of native and non-native grass and shrub species including blue grama (*Bouteloua gracilis*), fernbush (*Chamaebatiaria millefolium*), snakeweed (*Gutierrezia sarothrae*), horehound (*Marrubium vulgare*), western wheatgrass (*Pascopyrum smithii*), little hogweed (*Portulaca oleracea*), and cliffrose (*Purshia stansburiana*).

Grasslands in WACA are often only a small patch amidst woodlands or shrublands. Most of the herbaceous species in the mapping area co-occur with shrubs, forming a steppe (grasses dominant with >10% shrub cover). Blue grama and mountain muhly (*Muhlenbergia montana*) typically dominate small meadows that are often adjacent to ponderosa pine, pinyon pine, and Utah juniper woodlands. In the moister areas in the uplands, muttongrass (*Poa fendleriana*), little bluestem (*Schizachyrium scoparium*), and squirreltail (*Elymus elymoides*) commonly occur. In the mesic canyon bottoms of Walnut Canyon fringed brome (*Bromus ciliatus*) is often the main grass species. In disturbed areas in the northeastern section of the park native grasses include blue grama, Fendler's threeawn (*Aristida purpurea*), and black grama (*Bouteloua eriopoda*). Non-native grasses in these areas include the invasive cheatgrass (*Bromus tectorum*) and western wheatgrass (*Pascopyrum smithii*), a grass often used in reseeding efforts.

Shrublands commonly occur in disturbed areas and along the canyon bottom. Shrubs that are typical of the previously disturbed areas include rabbitbrush (*Ericameria nauseosa*) and snakeweed. These species are both native to the area; however, they thrive in areas of disturbance. Shrublands often occur on the limestone terraces on the north rim with a warm southern exposure, with common species including fernbush, barberry (*Mahonia fremontii*), banana yucca (*Yucca baccata*), cliffrose, and mountain mahogany (*Cercocarpus montanus*). Shrub species also occur in small patches that are inter-fingered as mosaics on the canyon bottom. Historical photography of the canyon bottom suggests that much of the riparian vegetation has increased substantially over the last 50 years, due to dams eliminating the natural water flow through the canyon (Brian 1992). Common species on the canyon bottom include riparian obligates such as dogwood and willows (*Salix* spp.) as well as species that prefer mesic habitats such as gambel oak, New Mexico locust, New Mexico olive, chokecherry (*Prunus virginiana*) and roundleaf snowberry.

Woodlands are the most common vegetation type in WACA and range from dense stands of trees on north-facing canyon walls, canyon bottoms, and in fire-suppressed areas to open stands of sparse trees in meadow-like areas. The most common trees in the upland environments are ponderosa pine, ranging from mid to high elevation areas in the park and pinyon pine and Utah juniper occurring mainly in the mid to low elevation areas. In the early 1900's large ponderosa pines were logged and the natural fire regime was altered, allowing for ponderosa pine to regenerate quickly and change the vegetation community from open meadows with low densities of ponderosa pine to areas of high density of ponderosa pine with a sparse understory community (Covington and Moore 1994). Much of WACA has a dense ponderosa pine stand structure due to these activities; however, some of WACA has larger ponderosa pines that have withstood these management activities. In the more mesic areas, Douglas-fir (*Pseudotsuga menziesii*) and Rocky Mountain juniper are the most common species, occurring in vegetation types with higher densities than woodlands, and are considered a forest vegetation type. A wide range of tree species occur in smaller patches in the linear corridors of the canyon bottom, including willow, box elder, narrow leaf cottonwood (*Populus angustifolia*) and Arizona walnut. Many of these species are restricted to mesic sites and require intermittent water flow. These community types typically have high cover and diversity of shrubs and understory species due to the additional water flow in these areas. Riparian obligate species include sedges (*Carex* sp.) and willows.

Four plant species of special concern also are suspected to occur in the park. These species include Arizona bugbane (*Cimicifuga arizonica*), Arizona leatherflower *(Clematis hirsutissima* var. *arizonica)*, Flagstaff pennyroyal *(Hedeoma diffusa)* and Chiricahua dock (*Rumex orthoneurus*).

Land use

WACA has had a long history of human land use. The earliest evidence of humans living in the canyon was 4000 B.C., with the highest density of prehistoric people residing in the area from 600 A.D. to 1250 A.D. (Short 1988) (Figure 7). The Spanish named these prehistoric people the "Sinagua". The Sinagua used the landscape for many different purposes, including cultivating crops for food and hunting and gathering of native plants and animals. Resources in WACA were used to provide heat and cooking fuels from the trees in the area, to provide shelter in the limestone cliffs, to make tools from the rocks, to make pottery from the clay, and to provide drinking water from the springs. The archaeological site density at WACA is greater than twice that of the surrounding ponderosa pine areas (see NPS Draft General Management Plan 2001), suggesting that the Sinagua probably significantly shaped the landscape surrounding Walnut Canyon.

The Sinagua mysteriously abandoned Walnut Canyon approximately around 1250 A.D. and until 1904, when the first ranger resided in the park, no other evidence exists of human occupation. Although no large settlements of humans inhabited Walnut Canyon after 1250 A.D., the surrounding landscape has been altered by historic and modern human activity. Historic and recent landscape altering activities include logging, hunting, fire suppression, housing development, and road and utility construction; these activities have altered the ecosystem processes. Cattle were known to be a constant problem for rangers in the areas where ruins were being maintained (Short 1988), until a fence was constructed in 1973 and livestock grazing was eliminated. Grazing continues adjacent the Monument as well as within the unfenced Monument boundary.

Figure 7. WACA Sinagua ruins restored and maintained by the NPS.

3. METHODS

In mapping and classifying the vegetation of WACA, we used the protocols and procedures established by the USGS/BRD (Appendix B) and described in *Field Methods for Vegetation Mapping, Standardized National Vegetation Classification System* (TNC and ESRI 1994a). The general work tasks were:

1. Project scoping and planning
2. Preliminary data collection and review of existing information
3. Aerial photography and base map acquisition
4. Sampling design development
5. Field data collection
6. Vegetation classification and characterization
7. Vegetation map preparation
8. Accuracy assessment

Project scoping and planning

WACA vegetation mapping incorporated the combined expertise and oversight of several organizations: 1) oversight and programmatic considerations were managed by the Center for Biological Informatics (CBI) of the USGS/BRD, 2) 3-Flagstaff National Monuments headquarters staff and WACA NPS personnel provided additional guidance on specific Monument needs, 3) aerial photointerpretation and cartographic mapping were provided by the USBR/RSGIG, 4) the CPRS provided field data collection, data analysis, the plant association local descriptions and key, and accuracy assessment, and 5) NatureServe provided data analysis review and the global plant association descriptions. The specific technical responsibilities assigned to the cartographic and ecological teams are listed below:

RSGIG responsibilities and deliverables

1. Obtain existing color-infrared aerial photography from NPS
2. Collect observation point data to determine photosignatures, determine a preliminary classification, and familiarize interpreters with plant community characteristics and their range of variation
3. Prepare a preliminary photointerpretation to assist field data gathering efforts
4. Attend a meeting to determine final mapping classes, both vegetated and land use, to be used for the final photointerpretation
5. Interpret aerial photographs
6. Transfer interpreted information to a digital spatial database and produce hard copy (paper) vegetation maps
7. Create digital vegetation coverages including relevant attribute information
8. Conduct field verification of the accuracy of the draft vegetation map
9. Produce Arc/Info export file of observation point locations
10. Provide any ancillary digital files developed during the mapping process
11. Document FGDC compliant metadata files (Appendix A) for all created spatial data
12. Prepare materials for the final report describing procedures used in preparing products

CPRS responsibilities and deliverables

1. Develop a preliminary vegetation classification for the study area from existing data
2. Determine field data sampling locations and strategy
3. Collect field data to identify and describe plant associations in the project area
4. Analyze field data and prepare a final classification, local association descriptions, and a key to plant associations
5. Field test the final classification, descriptions, and plant association key
6. Collect accuracy assessment points, analyze them against the final photointerpretation and prepare statistics describing map accuracy
7. Produce Arc/Info export file of sampling locations, vegetation relevé and accuracy assessment locations, MS Access database file of classification relevé and accuracy assessment observations, and jpeg image files of classification relevé photos
8. Develop FGDC compliant metadata files (Appendix A) for all vegetation classification relevé and accuracy assessment coverages and databases
9. Prepare a final report CD with all compiled products

NatureServe responsibilities and deliverables

1. Review vegetation classification developed by CPRS
2. Develop global plant association descriptions
3. Include newly described plant associations into the NVCS and present on a public website (www.natureserve.org/explorer/)

A scoping meeting was held in March 1999 at the NPS office in Flagstaff, Arizona. The purpose of this meeting was to inform Monument staff and interested neighbors about the USGS-NPS Vegetation Mapping Program, learn about the Monument management and scientific concerns, discuss and gather existing data, develop a preliminary work schedule with assigned tasks, obtain a commitment from the Monument to issue collecting permits, identify possible areas of cooperation with neighbors and partners, and define the project boundaries.

Park management issues and concerns that a vegetation map could help with were identified during the scoping meeting and included: increase in small diameter ponderosa pine (*Pinus ponderosa*) trees, viability of floodplain plant communities prior to the Santa Fe Damn, understanding historical logging of ponderosa pine, rare plant species in the Monument, adequate sampling in the diverse vegetation communities, encroaching urbanization from Flagstaff, and the sensitivity of archeological resources in relation to the vegetation types.

The mapping area was set at 20,732 ac (8,390 ha), including 3,637 ac (1,472 ha) within the Monument boundary. The additional USDA-FS, state trust, and private acreage surrounding the Monument were included because of its management interest to the NPS.

Preliminary data collection and review of existing information

To minimize duplication of previous work and to aid in the overall mapping project, we obtained existing data including maps and reports from various sources. Monument staff provided digital and/or hard copy background material for the project boundary and other digital files. Site and topographic maps were obtained from both the NPS and the Coconino National Forest. Digital elevation model files (DEMs), digital line graphics (DLGs), and digital raster graphics (DRGs) were obtained from the USGS. The USGS prepared digital orthophoto quarter-quadrangles (DOQQs) to be used as base maps for the digital transfer of data interpreted from the aerial photographs. A preliminary list of plant associations and local land use types was prepared following a field reconnaissance survey conducted at the time of the scoping meeting.

Aerial photography and base map acquisition

NPS (Fort Collins, CO) provided the aerial photography used in this project. The photographs are color infra-red (CIR) and were acquired on October 8, 1996 by Merrick & Co. of Aurora, Colorado. They were taken at the 1:12,000 (1 in=1000 ft, 1 cm=102 m) scale. The photographs were produced as 9 in x 9 in diapositives. Overlap for these photos averaged 50-60% and sidelap between flight lines was approximately 30-40%. Flight lines of aerial photography were acquired for photointerpretation of vegetation types (Figure 7).

We acquired base maps, standard USGS DOQQs, for geo-referencing the vegetation map from the NPS. These maps are black-and-white, with a one-meter per pixel resolution, UTM coordinate system, and NAD83 datum. The photos used to create the DOQQs were flown in October 1997. The DOQQs used for this project are: Flagstaff East (NE and SE quarter quads) and Winona (NE, NW, SE and SW quarter quads).

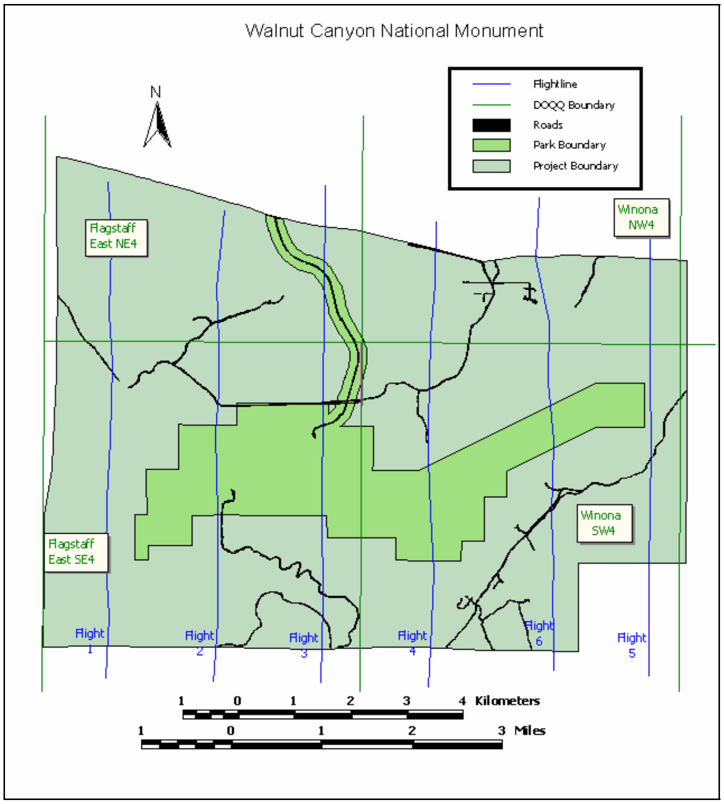

Figure 8. Aerial photo flightlines and DOQQ boundaries used for the WACA vegetation map.

Sampling design development

A gradsect sampling design was used to divide the WACA study boundary into 'environmental types' to stratify for field sampling. This division into environmental types was based on the assumptions that site characteristics determine vegetation community types, site characteristics repeat across the landscape, and that selective sampling within these sites provides accurate representation of plant community types (Austin & Heyligers 1989).

The gradsect was developed combining abiotic data of terrain types and elevation classes. Terrain types were identified from the USDA – FS Terrestrial Ecosystem Survey (TES) mapping data for the Coconino National Forest (Miller et al. 1991). We identified elevation classes from a scoping session with USGS, BOR, and NPS scientists and managers. Six elevation classes were developed from a Digital Elevational Model (DEM) and were combined with the TES data to produce unique environmental types for field sampling.

Forty-eight new environmental types were determined in the uplands. Fifty relevé locations were allocated within these areas to guide sampling. Within our selected environmental types we initially determined placement of relevés based on road accessibility and land ownership access. Some of the environmental types were not sampled due to inaccessible areas, occurrences of less than the minimum mapping unit of ½ hectare, and placement of types on private land.

We determined that environmental types along the canyon walls were often too difficult and dangerous to access. We implemented new tools to sample along the canyon walls and within the canyon bottom. Laser binoculars were lent to the program from Karl Brown of the Center of Biological Informatics (CBI). The binoculars provide locality information in UTM using the distance and azimuth offset of targeted locations in conjunction with the GPS Precision Lightweight GPS Receiver (PLGR) system. These observations provided information on dominant tree species; however, they did not provide additional data on the understory species. Thus, the complexity of strata of the canyon wall vegetation was not sampled as extensively as the upland relevés. These canyon wall relevés were used as reference relevés, but were not included into the statistical analysis.

Sampling on the canyon bottom was also based on accessibility. Relevés were completed using laser binoculars and when possible field sampling. Due to the density and heterogeneity of the vegetation on the canyon bottom, we clustered relevés in five locations. Strict allocation of observations by environmental types on the canyon bottom was not practical in sampling these habitats.

Field data collection

RSGIG ecologists conducted reconnaissance field surveys during which photointerpretive observation sites were sampled (in June 1999, May 2000, and June 2001). RSGIG ecologists photographed representative photosignatures and noted their position on the landscape, collected data at sites representative of distinctive photosignatures, and recorded field observations directly on Mylar overlays on individual aerial photos. Photointerpretive observations also guided the development of a draft list of map classes. The data collected described the habitat and vegetation structure and composition. Specific information recorded at each observation point included Universal Transverse Mercator (UTM) X-Y coordinates (NAD83 datum), dominant species cover estimates, and a brief description of the environmental characteristics (Appendix C).

The RSGIG team also conducted joint field sessions with CPRS plant ecologists to exchange observations, become familiar with field methodologies for vegetation relevé data collection, and discuss the project area. These joint sessions helped the ecologists become more familiar with the relationship of plant associations to photosignatures.

In August-September 1999 and July-September 2000 classification relevé sampling was conducted throughout the entire WACA project boundary. We used standardized methods (Muller-Dombois 1974, USGS-NPS 2000) to sample 109 classification relevés. The field team subjectively determined field relevé positioning within each environmental type visited so as to represent vegetation assemblages that were relatively dominant, homogenous, and covered a minimum mapping unit area of half a hectare. The field team also sampled special features and unique vegetation types within the environmental assemblages with specific interest to the park.

Typically we measured 1,000 m^2 circular plots, also known as vegetation relevés, in sparsely vegetated areas. We selected 1000 m^2 relevé as our standard as the vegetation of the area is relatively sparse and this size better represents the 0.5ha MMU than a 400 m^2 relevé (20% vs. 8%). Other vegetation studies of arid lands have also used this relevé size (Thomas et al 2003) and State Heritage ecologists recommended this size for arid and semi-arid vegetation (T. Keeler-Wolf pers. comm.). In areas of dense vegetation, such as riparian corridors, we would lower our relevé size to 400 m^2. Additionally, if rectangular or square areas better represented the vegetation patch shape we used this relevé layout instead, as found in dense riparian corridors within Walnut Canyon and its side canyons.

We recorded the vegetation and habitat characteristics using a standardized datasheet (Appendix C). We characterized habitat characteristics by recording the classification relevé slope, aspect, elevation, soil characteristics, topographic position, and landform types. We also recorded the community types (either wetland or upland). We also took two photographs that best represented the vegetation of the site and recorded the angles they were photographed from. Site UTM (NAD 83 datum), recorded by a Precision Lightweight Global Positioning System (GPS) Receiver (PLGR), landownership, and USGS quad were documented. We recorded basic vegetation descriptions of class, strata layer, and percent cover for all vascular plant species within a classification relevé. We subdivided the species into three different strata layers (tree, shrub, and ground layer) and estimated total percent cover of all species within each stratum. We estimated total vegetation cover and cover by strata layer (total tree, shrub, and ground cover). Since cover was estimated independently for each stratum, areas with dense canopy cover may have greater than 100% total cover. We also measured each tree with >10 cm dbh (diameter at breast height). In addition, we included separate calculations of percent cover for individual exotic and sensitive species as well as estimated total percent cover in each classification relevé.

The field data were entered into a Microsoft Access 2000 database. Plant names were standardized to the PLANTS (USDA, NRCS 1999) nomenclature. However, if The Nature

Conservancy (TNC) western preliminary alliances descriptions (Reid et. al. 1999) used synonymous nomenclature for a species name, this name was used instead in order to standardize our vegetation classification. After the data was entered, we also performed a spatial and data entry quality control check.

Vegetation classification and characterization

We based vegetation classification on guidelines developed from the National Vegetation Classification (NVC) (TNC and ERSI 1994b) and the Vegetation Classification Standard (NVCS) adopted by the FGDC (1997). The NVC classifies vegetation on seven hierarchical levels with the finest levels of the classification being the alliance and the association (Figure 9).

Physiognomic and Floristic Hierarchy

SYSTEM: TERRESTRIAL

CLASS woodland

SUBCLASS evergreen woodland

GROUP temperate or subpolar evergreen needle-leaved woodland

SUBGROUP natural/semi-natural

physiognomic levels FORMATION rounded-crowned temperate or subpolar evergreen needle-leaved woodland

floristic levels ALLIANCE *Pinus ponderosa* Woodland Alliance

ASSOCIATION *Pinus ponderosa / Bouteloua gracilis* Woodland

Figure 9. An example of the NVCS physiognomic and floristic hierarchy using the *Pinus ponderosa* / *Bouteloua gracilis* association.

The goal of the USGS-NPS vegetation mapping program is to classify vegetation types to the association level. The definition of an association as put forward by the Ecological Society of America Vegetation Classification Panel is “A vegetation classification unit consistent with a defined range of species composition, diagnostic species, habitat conditions, and physiognomy” (Jennings et al. 2003). Occasionally, a vegetation type cannot be defined to the association level, and the vegetation is described to the coarser alliance level. An alliance consists of a group of plant associations that share a uniform physiognomy and is characterized by one or more diagnostic species, which at least one of these species is found in the uppermost vegetation stratum (Mueller-Dombois and Ellenberg 1974).

Associations are named by the dominant and/or indicator species occurring in the community. If more than one species is characteristic of the association, then the species in the dominant strata is listed first and separated by a forward slash (/) from species in the lower strata or if species occur in the same strata they are separated by a dash (-). Parentheses are used when species are frequently present, but do not necessarily occur all the time, yet are considered an important part of the community structure when present. The nomenclature for alliance is based on the dominant and diagnostic species, and include at least one species from the uppermost stratum in the alliance name.

We initially analyzed the vegetation using multivariate classification analyses. We organized matrices of species absolute cover by relevé (typically row) and species (typically column). These were extracted from an Access database and transferred to a vegetation classification and ordination software program, PC-Ord, v 4.10 (McCune and Mefford 1999). Six matrices were examined: 1) all relevés, 2) relevés with greater than 60% cover tree species, 3) relevés with greater than 25% (but less than 60%) cover tree species, 4) relevés with greater than 25% cover shrub species (and less than 25% cover tree and herbaceous species), 5) relevés with greater than 25% cover grass and forb species (but less than 25% cover tree or shrub species) and 6) relevés with less than 25% cover. We calculated the cover of trees, shrubs or grasses in a relevé by adding the separate cover estimates for each species of that particular lifeform. Cover estimates needed to be summed, since the total vegetation calculated in the field was based on the strata layer, not on the lifeform. Many species occur in all three strata layers (for example, ponderosa pine commonly occurred in the ground (small saplings), shrub (medium saplings), and tree layer). We based the percentage used to separate each lifeform type on criteria for NVCS formation classes developed by the FGDC as interpreted by NatureServe (Grossman et al. 1998, Reid 2000 pers. comm.). Some relevés had greater than 25% total cover but less than 25% of tree, shrub or herbaceous cover. In those cases the relevé was assigned a formation class based on the dominant lifeform.

We used multivariate ordination algorithms within PC-Ord to examine species association patterns in each matrix. An agglomerate unweighted pair group method with arithmetic mean (UPGMA) group averaging method, commonly known as cluster analysis, we next applied with the distance measure defined as Sorensen's coefficient (also known as the Czekanowski or Jaccard coefficient). We examined preliminary descriptions of alliances from An Alliance Level Classification of Vegetation of the Coterminous Western United States (Reid et. al. 1999) referred to hereafter as the TNC western preliminary alliances, to identify potential alliances. We labeled each relevé in the cluster analysis with an appropriate alliance and association label based on iterative examination of the alliance descriptions, the matrix of relative cover scores for each species, and the cluster analysis graphic dendrogram.

NatureServe reviewed the results of the data analysis, and the initial placement of relevés within associations and alliances. A number of vegetation types identified from the analysis represented associations already documented in the NVCS, and registered in NatureServe Explorer, an online encyclopedia of life (www.natureserve.org/explorer/). In some cases the vegetation types from the analysis did not correspond to existing associations in the NVCS (i.e. appeared to be new associations), and these were treated in three different ways according to the amount of information supporting them from the project. Those with ≥ 3 relevés, or with fewer relevés but covering substantial mapping area were incorporated into the NVCS as new plant associations. Those with few relevés (typically <3), seemingly uncommon or of uncertain floristic composition, were designated as "provisional" plant associations in the NVCS, and require additional sampling to fully understand their floristic and ecological characteristics. The last group of vegetation types were those represented by only one or two relevés, that seemed essentially unique to the WACA project area. Until further inventory is completed, these should be thought of as "local" vegetation assemblages and we describe these throughout the report as local assemblages. A few relevés were classified only to the coarser alliance level.

A dichotomous key to the vegetation association/alliances as well as to the corresponding map classes was developed prior to the 2001 accuracy assessment field season. We used the key in the 2001 data collection for accuracy assessment. We made slight modifications before using the key in the second round of accuracy assessment observations collection during the 2002 field season (Appendix D).

Vegetation map preparation

The five following steps were used to create the WACA vegetation map: 1) map class development, 2) aerial photograph interpretation, 3) digital transfer, 4) map validation, and 5) metadata. Following these steps, we performed a more formal accuracy assessment of the vegetation map to determine errors of omission and commission with the goal of achieving a minimum of 80% map accuracy.

<u>Map class development</u>

A relatively simple vegetation and land use classification was prepared to guide a preliminary aerial photointerpretation, completed by RSGIG in June 1999. CPRS ecologists also used this preliminary work to better examine the landscape and vegetation features of the project area during vegetation relevé sampling activities. So as not to bias field researchers, each polygon delineated was given a consecutive number, with attributes for each polygon number listed in a separate table.

Final WACA map classes used for interpreting the aerial photographs were derived (1) from plant associations described by CPRS, (2) from the Anderson (1976) Level II land use classification system, and (3) from special requests by NPS staff.

The Vegetation Mapping Program standard is a one-to-one correspondence between NVCS plant associations and map classes. Anderson Level II land use classes describe polygons that are not covered adequately by the NVCS, including modified landscapes and developed areas. Finally, special vegetation types, habitats, and land use recognized by NPS staff but not part of the NVCS were mapped. In some cases, one NVCS association corresponded to one mapping class; more often, because of difficulties in interpreting the CIR photographs, map classes described more than one plant association and were combined into mosaics or complexes of associations. For instance, we combined the two mountain meadow grassland associations (*Bouteloua gracilis* Herbaceous Vegetation and *Muhlenbergia montana* Herbaceous Vegetation) into a Blue Grama – Mt. Muhly Grassland Group map class.

In some instances, NVCS association map classes provided less detail than could be photo delineated. In these instances, we defined and mapped additional information of species composition (e.g. Ponderosa Pine – Pinyon Pine – Juniper / Blue Grama Woodland and Ponderosa Pine / Mixed Graminoid Woodland Complex map classes are both derived from the *Pinus ponderosa / Bouteloua gracilis* Woodland association). This level of detail provided additional refinement in the mapping classes and provides additional information to park management.

The Anderson Level II land use classes included semi-natural vegetation and cultural types, i.e. roads, facilities, residential land, reservoirs and pastures, etc. We developed special map classes to represent the geologic and landform features with sparse vegetation and include Sparsely Vegetated Coconino Sandstone, Sparsely Vegetated Kaibab Limestone, and Sparsely Vegetated Intermittent Drainage Channel. We developed a map class to represent NVCS vegetation associations defined only through the photointerpretative process, Introduced Western Wheatgrass Grassland. Finally, we developed a special map class for prairie dog towns, Common Horehound – Prairie Dog Town, that is not represented in the NVCS. The crosswalk showing how associations relate to map classes is shown in Table 1.

Aerial photograph interpretation

RSGIG identified patches of homogenous vegetation (areas on the photos with similar tone, texture, color and landscape position) using NVCS-derived map classes, field notes, photointerpretative observations, and classification relevés to prepare the GIS vegetation database.

We conducted photointerpretation using aerial photographs with sheets of translucent Mylar. The aerial photos and their overlays were backlit on a light table and their photographic signature read. Using a stereoscope helped to recognize three-dimensional features. Corner and side tics, photograph, and flight line number were marked on each Mylar sheet. We delineated polygons using a 0.5 mm lead pencil, with only the center portion of each aerial photograph interpreted to minimize the effects of edge distortion. In order to insure completeness and accuracy, digital transfer specialists reviewed all of the interpreted photos for consistency and recommended changes where necessary.

Digital transfer

The transfer process removes much of an aerial photograph's inherent distortion and ties the interpreted polygons to real-world coordinates so they can be digitally automated. An ArcInfo GIS database was built for WACA vegetation using in-house protocols.

The protocols consist of a shell of Arc Macro Language (AML) scripts and menus (nearly 100 files) that automate the transfer process, thus insuring that all spatial and attribute data are consistent and stored properly. In order to accommodate several technicians working on the database at the same time, the work was divided by quarter-quad area (i.e., one vegetation coverage per quarter-quad area). The actual transfer of polygons and their attributes from the interpreted aerial photographs to a digital, geo-referenced format involves two techniques: (1) scanning the interpreted line work and (2) on-screen digitizing some land use classes. Both techniques require a background image (base map). We used USGS DOQQs as the base maps for this project. Once all the transfer work was complete, all the individual vegetation coverages were combined into one seamless coverage.

The scanning transfer technique used for WACA involved a multi-step process whereby the Mylar overlay sheets produced by the photointerpreters were scanned into a digital form. We then converted the digital image file (.tif) created from the scanned sheet to a vector file using RSGIG-developed AMLs. The vector file or 'line coverage' was then geo-referenced to the orthophoto base map. Essential to this process is to match the scale and position of features on the photographs with the scale and position of the same features on the orthophotos. Technicians accomplished this by adjusting the scale of the scanned Mylar between known control points using computer program routines until the adjustment was considered a good fit (Figure 10).

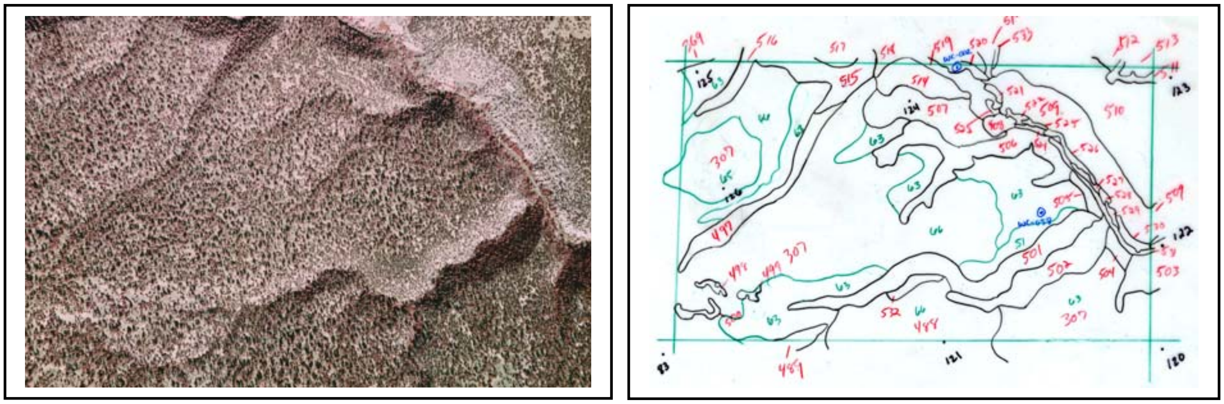

Figure 10. An example of photointerpretation at WACA of aerial photo 3-004 and corresponding (scanned) Mylar overlay.

Any remaining land use classes not already scanned (such as roads) we transferred by means of on-screen digitizing. This process entered interpreted line work on the Mylar sheets into the GIS database by manually tracing digital lines (using a mouse) on a computer monitor screen with the DOQQ as a background image. The completed line work for each photo was edge matched. Finally, we created the polygon topology and attribute information added to produce a digital vector (polygon) coverage. All the individual coverages (one per photo) were then combined into a single vegetation coverage.

Each polygon in the final coverage for WACA was given attributes pertaining to map classes, the corresponding aerial photograph number, NVCS information (ecosystem, physiognomy, association, alliance, class, subclass, group, subgroup, formation, and database codes), and other comments related to the distribution and photointerpretation.

<u>Map validation</u>
A draft hard copy vegetation map at the 1:12,000 scale was printed and checked against the interpreted aerial photographs. As a final internal accuracy check, we applied photointerpretative observations and classification relevés over the vegetation map to determine if the polygon labels matched the field data.

Finally, map validation occurred prior to the accuracy assessment. Staff from RSGIG conducted a field trip in conjunction with other meetings in Flagstaff, AZ in January 2001 to refine and assess the initial mapping effort. On this trip we collected additional photointerpretative observations and ground-truthed aerial photograph signatures using landmarks and GPS waypoints. Map classes were lumped or split to account for inadequacies in the final photointerpretation.

Metadata

Metadata are required for all spatial data produced by the federal government. RSGIG used SIMMS™ software and CPRS used ArcCatalogue software to create the FGDC-compliant metadata files attached to the spatial databases and to this report (see Appendix A). The metadata files explain the vegetation coverage and ancillary coverages created by RSGIG, the classification relevé data coverage created by CPRS, and the accuracy assessment observation data created by CPRS.

Accuracy assessment

CPRS field staff conducted the formal accuracy assessment of the WACA vegetation map and vegetation association key. We conducted field surveys in two phases, from September 4 to September 25, 2001 and from October 25 to December 12, 2002. Phase one of sampling was designed using a preliminary vegetation map and allowed a majority of the field accuracy observations to be collected for all the map classes. Phase two was planned with the final vegetation map and the design ensured that all necessary sampling points were collected for assessment of the final vegetation map. We pooled the accuracy assessment observations from 2001 and 2002 to create the reference dataset to assess the accuracy of the map classes on the 2001 final vegetation map using both standard criteria for accuracy (exact match) and 'fuzzy' categorization criteria for accuracy (acceptable, understandable, vaguely similar, and complete error).

Before developing the sampling design for accuracy assessment observations, we checked the topology and data structure for the vegetation coverage by running a check for node errors and label errors. We combined joining polygons with the same attribute.

Field sampling locations were then selected for each map class based on the total cover of each vegetation class in the coverage, where map classes with more cover had more reference points assigned, and vice versa. The required number of polygons to be sampled was determined by applying USGS-NPS vegetation mapping program criteria (Table 1) that considers the number of polygons in each map class and the total area of each map class in the vegetation coverage and seeks to ensure a 90% confidence level and a sample error of 10%. We assigned random numbers to the polygons and selected the required numbers of polygons for each map class plus 5 to 10 extra polygons in the case that some polygons could not be reached.

Table 1. USGS-NPS vegetation mapping program criteria used for determining accuracy assessment sampling numbers.

Scenario	Description	Polygons in map class	Area occupied by map class	Recommended number of samples in map class
A	Abundant. Many polygons that cover a large area.	≥ 30	≥ 50 ha	30
B	Relatively abundant. Class has few polygons that cover a large area.	< 30	≥ 50 ha	20
C	Relatively rare. Class has many polygons, but covers a small area. Many polygons are close to the MMU.	> 30	< 50 ha	20
D	Rare. Class has few polygons, which may be widely distributed. Most or all polygons are close to the MMU.	≥ 5, ≤30	< 50 ha	5
E	Very rare. Class has too few polygons to permit sampling. Polygons are close to the MMU.	< 5	< 50 ha	Visit all and confirm

We initially identified 461 accuracy assessment sampling locations in 2001 and 566 in 2002, including alternate locations in case a targeted point could not be evaluated. We observed 270 locations in the field in 2001 and 126 in 2002. Some observations from 2001 were not included in the pooled 2001 and 2002 accuracy assessment observation dataset used to calculate the accuracy statistics. We eliminated observation data when both 2001 and 2002 accuracy assessment observations occurred within a single polygon on the final vegetation map. In such cases, the accuracy assessment point assessed in 2001 that assessed the largest area of the polygon was selected to be included in the pooled accuracy assessment observation dataset.

In 2001, sampling locations in polygons greater than the MMU of 0.5 ha were visited; however, if the required number of samples for a map class could not be obtained in polygons greater than the MMU, polygons less than the MMU were then visited for field observations. In 2002 all polygons were included in the sampling design regardless of the size of the polygon. In both 2001 and 2002, polygons that were greater than the MMU had sampling locations randomly assigned in the polygon excluding a 5-m buffer from the polygon edges. In polygons that were less than the MMU, we used the centroid of the polygon for the sampling locations to minimize edge effects from adjacent polygons. In 2001, polygons greater than the MMU, a 0.5 ha area

(MMU) was surveyed. In polygons less than the MMU, a radius (less than the MMU) was provided to the field team to ensure that they would not survey in an adjacent polygon and they were to survey the entire radius prior to determining the map class. If the polygon size was less than a 10-m radius (0.03 ha), than a polygon map was provided to the field team to orient them within the polygon and the whole polygon was to be surveyed. In 2002, the field team had a polygon map for all polygons sampled. In polygons greater than the MMU, the field team was to survey an area equivalent to the MMU prior to making a final determination of the map class. In polygons less than the MMU, the entire polygon was surveyed.

<u>Data collection</u>

The CPRS field team had a list of UTM coordinates for each sampling point, the area and length of the polygon, and the shortest distance to an adjacent map class. In the first phase, for those polygons with less than the MMU (<0.5 ha), maps were provided of each small polygon to be observed that showed a distance scale and direction orientation. In the second phase, the field ecologists had polygon maps for all polygons observed including those >0.5 ha. The field ecologists went to the sampling location indicated by the UTM coordinates and assessed an area around that location no larger than the MMU (2002) or within an assigned radius about the sampling location (2001). Sampling radii were predetermined such that the area observed was contained within the polygon being assessed. We recorded accuracy assessment observations, including the following: the plant association or map class within the assigned radius about the sampling location, confidence in the decision according to the descriptions of the association/map classes in the field key (using the following four categories: exact, good or some problems, poor, or none that fit), explanation of confidence if less than exact (including alternative map class possibilities), UTM coordinates (easting, northing), altitude, and GPS error (using the Garmin 45XL, Garmin Corporation, 1996). See Appendix C for an example datasheet. The field biologists sometimes could not get to a pre-selected sampling location; in these cases, the polygon was assessed remotely if possible or a different polygon was selected for observation from the list of replacement locations.

During the accuracy assessment fieldwork, ongoing discussions between the field biologists and project ecologists/botanists allowed for refinement of the NVCS plant association and map class key, as well as some of the vegetation classifications. We implemented these changes in the key and reflect some changes between the first and second round of sampling in the interpretation of the association map class concepts. Revisions to the 2001 key included, in some cases, relaxation of some of the quantitative criteria to identify the plant associations so that more qualitative evaluation of the label was possible in the field. We made this change to allow more breadth in the interpretation of the map classes so that variability in the label that may not have been measured on the classification relevés could be accounted for within the field key. We accounted for these changes during the accuracy assessment analysis described below.

<u>Accuracy assessment analysis</u>

Accuracy assessment analysis was done by comparing the map class observed in the field (field observation or reference data) with the map class mapped at the same location on the final vegetation map (map class data). We made these comparisons using standard accuracy assessment analysis, identified as part of the USGS-NPS Vegetation Mapping Program (http://biology.usgs.gov/npsveg/aa/toc.html), and a modified ‘fuzzy set’ accuracy assessment analysis (Klopfer et al. 2002). 2001 and 2002 field observation data, except for those observations that were remotely assessed in 2002, were overlain onto the final vegetation map to determine the corresponding map class for each location. In these cases, the map class that was identified for the target polygon in the sampling design was assigned to the map class data rather than the reference map class.

For each standard and fuzzy set comparison, a contingency table was developed to compare the reference data with the map class data. The contingency table lists reference data values in the columns and map class values in the rows. The number of each reference data and map class pair for all sampling locations is indicated at each row/column intersection in the matrix (see Table 7 for an example). Correct mappings are indicated on the table where the row and column values are the same and typically occur on the diagonal on the matrix (yellow highlight on Table 7). The contingency table is used to calculate a variety of statistics describing the map performance: omission accuracy (also known as producers accuracy), commission accuracy (also known as users accuracy), the overall accuracy, and the Kappa index.

Initial analysis revealed a low overall accuracy and therefore we examined the errors associated with each observation using a modified 'fuzzy set' analysis to rank the type of error (Klopfer et al. 2002, Falzarano and Thomas In Press). In this assessment, we use five criteria: exact match, acceptable error, understandable error, vague similarity, and complete error, to assess the fit between the reference data and map class for each sampling location (Table 2). We included only criteria 5, 4, and 3 in our analysis, since criteria 2 and 1 did not provide any additional information.

Table 2. WACA definitions used in the 'fuzzy set' analysis classifications.

Criteria	Descriptions
5	**Exact Match**: The reference data is an exact match to the map class.
4	**Acceptable Error**: If any of the following criteria were met than the case was considered acceptable error: 1) The reference data are the same as a map class in the nearest adjacent polygon and is within 12 meters of that polygon, adjusting for National Map Accuracy Standards for horizontal accuracy (Robinson et al. 1984), 2) The reference label is in a 2001 polygon that became an inclusion below the MMU in 2002 and had similar floristic and structural composition of the larger 2002 polygon, 3) The reference data has an alternative reference label that was described in the field, which was correct for the map class, 4) The reference label described using the 2001 plant association field key was an alternative correct map class described using the 2002 map class field key, or 5) The reference label is the same NVCS association as the map class.
3	**Understandable Error**: The map class has similar structural composition and species dominance.
2	**Vague Similarity**: The map class has a similar formation type, but not similar species composition.
1	**Complete Error**: No similarity in the species or structural composition.

A contingency table was created for three criteria: 1) exact match— a correct map class was considered to occur where there was exact match between the reference data and map class data, 2) acceptable error—a correct label was represented by exact (criteria 5) and acceptable (criteria 4) matches between reference data and map class data, and 3) understandable error—a correct label was represented by exact (criteria 5), acceptable (criteria 4) and understandable (criteria 3) matches between reference data and map class data. The standard accuracy assessment are the same criteria as an exact match in the modified fuzzy set analysis.

An example of acceptable error was the case of a field observation of the map class Limestone Rim Complex mapped as Pinyon Pine – Utah Juniper / Blue Grama Woodland. In this example, the field observation was 9 m from the nearest polygon, with a GPS error of 5 m, and the closest polygon was labeled Limestone Rim Complex. Due to the vertical relief in this area and the close proximity of the accuracy assessment observation to a polygon with a matching map class, we believed that the misidentification may be a locational error either on the map or in the field rather than a photointerpretation misclassification.

Acceptable error was also determined where interpretation of the field observation differed between the preliminary and final map. For example, a field observation of Blue Grama – Mt. Muhly Grassland Group was made in 2001 and its location was in a small (1.6 ac/0.661 ha) polygon in the preliminary map. However, on the final map, the sampling location for this observation was now included in a larger polygon (2,548 ac/1,031 ha) labeled Ponderosa Pine / Mixed Graminoid Woodland Complex. The notes for the original observation described the field situation as high tree cover. In this case, where the scale of consideration changed, we considered the field observation an acceptable match to the final map class.

Another case of acceptable error was where the accuracy assessment observation was classified as Pinyon Pine – Utah Juniper / Blue Grama Woodland, and on the field sheet it was described as poorly fitting the polygon with an explanation that the polygon also might contain the map class Ponderosa Pine / Gambel Oak Woodland. The map class was actually Ponderosa Pine / Gambel Oak Woodland. In this case two different map classes may have occurred within the same polygon and since this map class was listed on the field sheet as an alternative map class, the accuracy assessment observation was considered an acceptable error.

Better understanding of the photointerpretation criteria resulted in some changes in the field key. We considered alterations of the field key from the version used in 2001 to the version used in 2002 in assigning acceptable error. For example, in the 2001 field key the map class Snakeweed / Modified Grassland Complex was identified by the presence of a few non-native or native weedy NVCS associations; whereas the map class was photointerpreted in 2002 to represent any area of recent landscape disturbance. In this case, native NVCS associations that were described as occurring in an area of human disturbance were re-evaluated using these new criteria and assigned acceptable error if the map class was Snakeweed / Modified Grassland Complex.

Another example of an acceptable error was where an accuracy assessment observation of Ponderosa Pine / Blue Grama Woodland was mapped as Ponderosa Pine - Pinyon Pine - Juniper / Blue Grama. The accuracy assessment observation was classified as the NVCS association *Pinus ponderosa / Bouteloua gracilis* Woodland, where the mapped class is *Pinus ponderosa*

(Pinus edulis – Juniperus osteosperma) / Bouteloua gracilis Woodland. For this map class, pinyon pine (*Pinus edulis*) and Utah Juniper (*Juniperus osteosperma*) do not necessarily need to be present in order to be placed into this association. Since the field observation contained the required ponderosa pine (*Pinus ponderosa*) and blue grama (*Bouteloua gracilis*) to match the map class, it was assigned to the acceptable error category.

An example of understandable error occurred where the accuracy assessment observation had a similar species composition and structure as the map class assigned to the polygon containing the observation. For example, Ponderosa Pine –Pinyon Pine - Juniper / Gambel Oak Woodland as the reference label and Ponderosa Pine –Pinyon Pine - Juniper / Blue Grama Woodland as the map class have the same structure and species composition, except for the understory community. In this case, it is likely that it was difficult for the photointerpreters to delineate the understory community.

Vaguely similar would include the case where the accuracy assessment observation (Ponderosa Pine / Mixed Graminoid Woodland Complex) structure was similar to the map class (Pinyon Pine – Utah Juniper/ Blue Grama Woodland); however, the species composition is not similar. An example of complete error was where the reference label (Pinyon Pine – Utah Juniper / Blue Grama Woodland) had no similarity with the map class (Sparsely Vegetated Coconino Sandstone) in terms of structure or species composition.

Where the accuracy assessment observation was determined to 'fit' the map class for a particular criteria, the accuracy assessment observation was 'reassigned' to the map class for the purposes of constructing the error matrix. Hence the diagonals on the error matrix show the sum of all accuracy assessment observation/map class pairs that were matches under the particular criteria being applied.

Overall total accuracy for each contingency table criteria as described above (standard analysis, acceptable error, and understandable error) was calculated by dividing the total number of correctly classified reference data points by the total number of reference data points. We also assessed individual map class accuracies for each of the criteria described above. To calculate the probability that a reference data observation has been correctly classified (producer's accuracy or omission error), the number of reference data points correctly classified is divided by the total number of reference data points in that map class. To calculate the probability that the mapped vegetation associations represent the associations actually found on the ground (user's accuracy or commission error), the number of correctly classified reference samples was divided by the total number of samples classified or mapped to that vegetation association.

Equations to calculate statistics for each criteria are described in the program documents, Accuracy Assessment Procedures (http://biology.usgs.gov/npsveg/aa/toc.html) and TNC and ERSI (1994c). Two-tailed, 90% confidence intervals for the binomial distribution were also calculated using JMP statistical software (SAS Institute, Cary, NC) using Score Confidence Interval Tables. Score Confidence Interval Tables are known to have better coverage probabilities with smaller sample sizes (Agresti and Coull 1998). To account for correct classifications due to chance, a Kappa index (Foody 1992; TNC and ERSI 1994c) was calculated also using JMP statistical software.

4. RESULTS

Field surveys

Forty-six photointerpretation observation sites were field sampled by RSGIG photointerpreters (Figure 11). One hundred and nine classification relevés, including 10 laser obtained relevés, were field sampled (Figure 12). At each classification relevé, we took two photos. Information recorded for each classification relevé and classification relevé photos are on the project CD (see Appendix A).

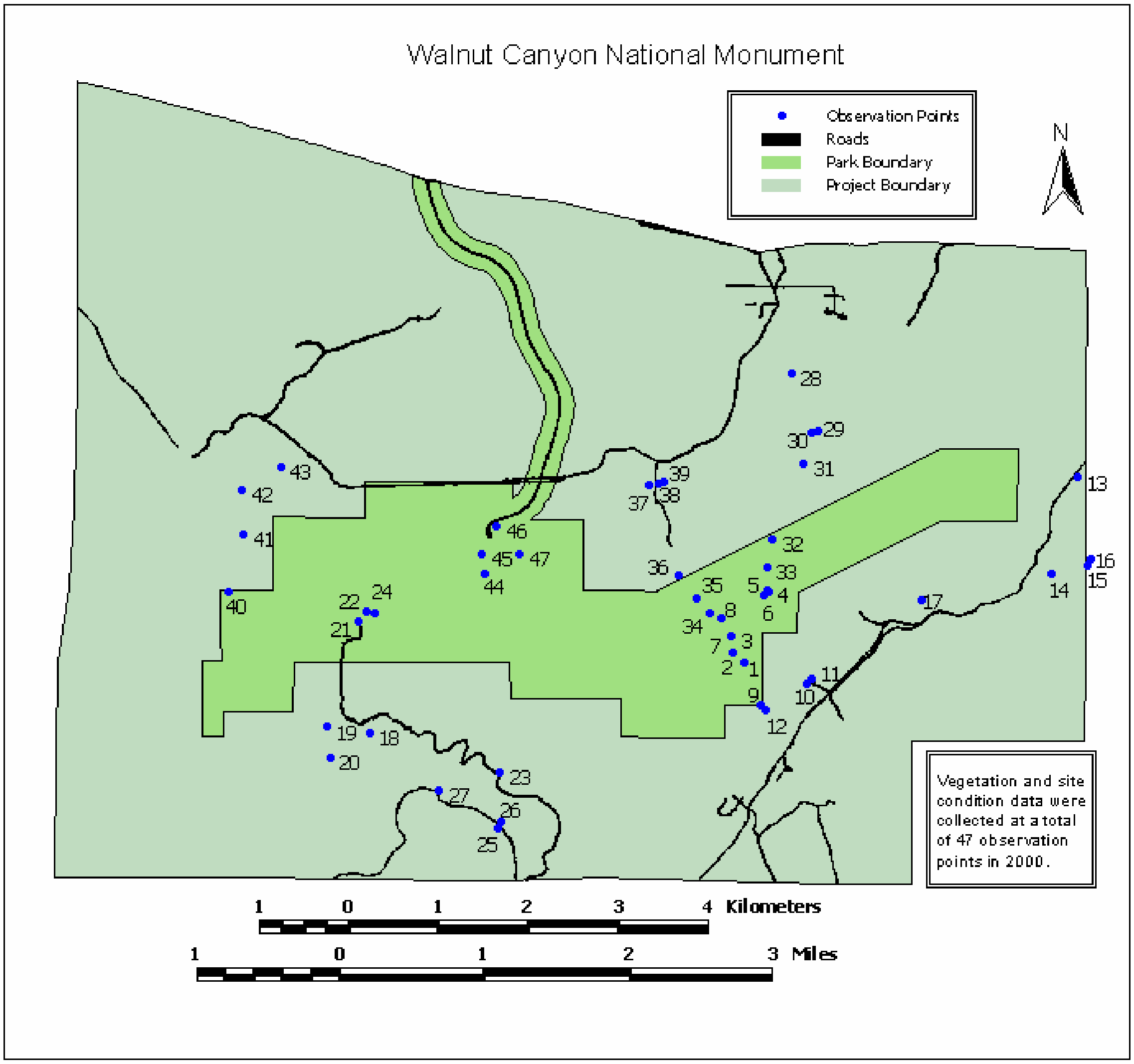

Figure 11. WACA photointerpretation observation point locations.

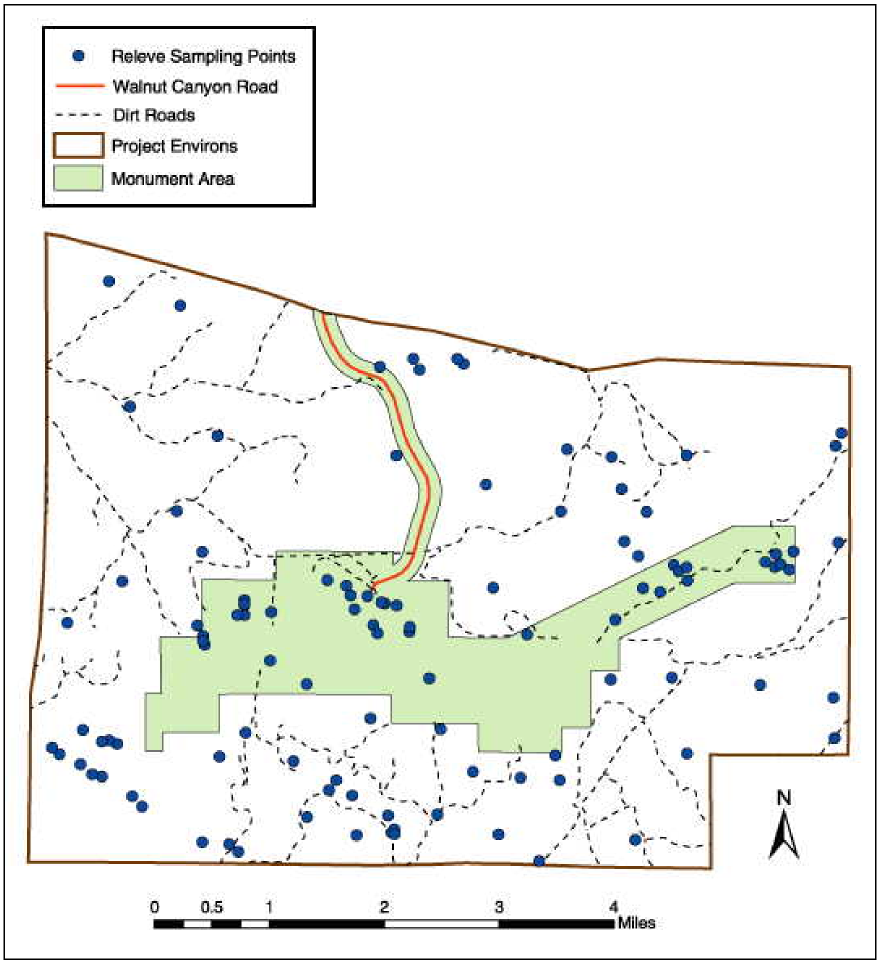

Figure 12. WACA classification relevé locations.

Vegetation classification

The NVCS classification resulted in a total of 13 alliances, 14 associations, one provisional alliance and two provisional associations, three Monument specific local assemblages, and one alliance and association described only through photointerpretation (Table 3). Full descriptions of the WACA vegetation associations, provisional associations, and local assemblages are located in Appendix E. A listing of all species identified during the course of this study can be found in Appendix F. Three local assemblages were identified as possibly being unique to WACA, these assemblages need further sampling on the Colorado Plateau to determine if they represent local vegetation types unique to WACA or if they are distributed across the landscape. We described one provisional alliance and two provisional associations as occurring frequently enough during the course of the study to be included as provisional in the NVCS, but they will need additional field data collected in other localities on the Colorado Plateau to support their addition as a NVCS alliance and association. Two alliances and three associations were newly described in the NVCS. The alliances, as grouped by formation, consist of one forest, four woodland, two shrubland one dwarf-shrubland, and seven herbaceous classes and the associations consist of one forest, six woodland, five shrubland, one dwarf-shrubland, and seven herbaceous classes. A field key to both the map classes and alliance/association classifications is listed in Appendix D.

Table 3. WACA National Vegetation Classification assignments.

Formation Class	Assignment	NVC Alliance	NVC Association	Relevé #
Forest	Association	*Pseudotsuga menziesii* Forest Alliance	*Pseudotsuga menziesii / Quercus gambelii* Forest	WC-005, WC-006, WC-009, WC-011, WC-013, WC-020, WC-021
Woodland	Alliance	*Juniperus osteosperma* Woodland Alliance	No Association	WC-068
	Alliance	*Juniperus scopulorum* Woodland Alliance	No Association	WC-012, WC-069
	Association	*Pinus edulis* Woodland Alliance	*Pinus edulis – (Juniperus osteosperma) / Bouteloua gracilis* Woodland	WC-003, WC-017, WC-018, WC-026, WC-027, WC-030, WC-031, WC-032, WC-043, WC-046, WC-047, WC-050, WC-061, WC-062, WC-076, WC-089, WC-092, WC-100
	Association	*Pinus edulis* Woodland Alliance	*Pinus edulis - (Juniperus* spp.*) / Cercocarpus montanus* Woodland	WC-016
	Association	*Pinus edulis* Woodland Alliance	*Pinus edulis – (Juniperus osteosperma) / Purshia stansburiana* Woodland	WC-028
	Association	*Pinus ponderosa* Woodland Alliance	*Pinus ponderosa – (Pinus edulis – Juniperus osteosperma) / Bouteloua gracilis* Woodland; *Pinus ponderosa / Bouteloua gracilis* Woodland	WC-025, WC-035, WC-044, WC-049, WC-053, WC-057, WC-058, WC-059, WC-060, WC-088
	Association	*Pinus ponderosa* Woodland Alliance	*Pinus ponderosa – (Pinus edulis – Juniperus osteosperma) / Quercus gambelii* Woodland; *Pinus ponderosa / Quercus gambelii* Woodland	WC-001, WC-004, WC-014, WC-019, WC-022, WC-023, WC-024, WC-045, WC-054, WC-055, WC-056, WC-064, WC-065, WC-066, WC-071, WC-072, WC-075, WC-077; WC-094
	Association	*Pinus ponderosa* Woodland Alliance	*Pinus ponderosa / Muhlenbergia montana* Woodland	WC-036, WC-037, WC-039, WC-040, WC-041, WC-070, WC-095
Dwarf-Shrubland	Provisional Association	*Gutierrezia sarothrae* Dwarf-shrubland	*Gutierrezia sarothrae* Modified Dwarf-shrubland	WC-067, WC-079, WC-082, WC-090, WC-098, WC-101
Shrubland	Provisional Alliance and Association	*Chamaebatiaria millefolium* Shrubland Alliance	*Chamaebatiaria millefolium - (Mahonia fremontii) – Yucca baccata* Shrubland	WC-002, WC-007, WC-008, WC-010
	Local Assemblage		*Chamaebatiaria millefolium - Forestiera pubescens* Shrubland	WC-015
	Local Assemblage		*Ericameria nauseosa - Gutierrezia sarothrae* Shrubland	WC-087
	Local Assemblage		*Acer negundo / Forestiera pubescens – Symphoricarpos rotundifolius* Temporarily Flooded Shrubland	WC-051, WC-052
	Association	*Quercus gambelii* Shrubland Alliance	*Quercus gambelii / Robinia neomexicana / Symphoricarpos rotundifolius* Shrubland	WC-029, WC-033, WC-034, WC-074

Formation Class	Assignment	NVC Alliance	NVC Association	Relevé #
Herbaceous	New Association	*Aristida purpurea* Herbaceous Alliance	*Aristida purpurea* Herbaceous Vegetation	WC-102
	Association	*Bouteloua eriopoda* Herbaceous Alliance	*Bouteloua eriopoda* Semi-desert Herbaceous Vegetation	WC-080
	Association	*Bouteloua gracilis* Herbaceous Alliance	*Bouteloua gracilis* Herbaceous Vegetation	WC-038
	New Alliance and Association	*Bromus tectorum* Semi-Herbaceous Alliance	*Bromus (tectorum, rubens)* Semi-natural Herbaceous Vegetation	WC-086
	New Alliance and Association	*Ericameria nauseosa* Shrub Short Herbaceous Alliance	*Ericameria nauseosa / Bouteloua gracilis* Shrub Herbaceous Vegetation	WC-078, WC-081, WC-083, WC-084, WC-085, WC-091, WC-093
	Association	*Muhlenbergia montana* Herbaceous Alliance	*Muhlenbergia montana* Herbaceous Vegetation	WC-042, WC-073
	Association	*Pascopyrum smithii* Herbaceous Alliance	*Pascopyrum smithii* Herbaceous Vegetation	This association was not sampled in the field; it was identified only in the photointerpretation

The classification relevés are categorized as non-vegetated (less than 5% total vegetation cover) or by NVC formation: forest, woodland, shrubland, shrub herbaceous (steppe), or herbaceous vegetation. Three map class complexes, however, are not categorized by a single formation but have intermixing of formations in these map classes. These complexes consist of the Limestone Rim Complex (the Kaibab limestone canyon rim), Canyon Floor Complex (the canyon bottom community), and Snakeweed / Modified Grassland (a recently disturbed/modified landscape).

Unvegetated patches at WACA are considered a land cover class and comprise less than 1% (94 ac/38 ha) of the total area mapped. The unvegetated to sparsely vegetated patches persist on the limestone and sandstone canyon walls as well as on the canyon bottom of Walnut Canyon in localized patches along the drainage channel. In small seeps on the canyon walls, various hanging garden species often occur. The drainage channel is unvegetated in areas where water scours the canyon bottom; however, the drainage channel has intermediate water flow with opportunistic riparian species emerging periodically between scouring events.

Forests are rare at WACA (~2% of the project area, 440 ac/180 ha) and only occur in small mesic areas, often on north-facing slopes of canyon walls, the canyon bottom, and side canyons. Douglas-fir (*Pseudotsuga menziesii*) is the only tree that was identified as occurring with high enough canopy cover to have a forest stand structure. The Douglas-fir forest often has Gambel oak (*Quercus gambelii*) in the understory.

Woodlands are the predominant vegetation type, covering approximately 80% of the project area (16,500 ac/6,680 ha). They occur on all landforms including uplands, canyon walls, canyon bottoms, and canyon rims. Woodlands comprise five alliances and nine associations of the 13 alliances and 17 associations described. None of the woodland alliances or associations are newly described, since many of the woodland communities at WACA commonly occur on the Colorado Plateau.

The main woodland tree species at WACA are ponderosa pine (*Pinus ponderosa*), pinyon pine (*Pinus edulis*), and Utah juniper (*Juniperus osteosperma*). The most common tree in the mapping area is ponderosa pine, ranging from the mid elevation ecotonal areas to the highest elevations in the project area. This species' density varies significantly in the project area, depending on fire and land use history. Mountain muhly (*Muhlenbergia montana*), blue grama (*Bouteloua gracilis*), and Gambel oak commonly occur in the understory of the ponderosa pine canopy. At the mid elevations ponderosa pine, pinyon pine, and Utah juniper woodlands co-dominate the canopy. This co-dominance occurs in approximately one-third of the project area. Even though this mix of species is not defined in the NVC as a separate association, we mapped these broad ecotonal communities as unique map classes since we believe they are unique ecologically. At the lower elevations, pinyon pine, and Utah juniper woodland with blue grama understory typically occurs on upland and canyon walls. In addition to these lower elevation areas, Utah juniper occurs in small homogenous stands in WACA's lower elevation uplands.

None of the NVC shrubland formations were mapped as separate map classes. All of the shrublands were combined into the Snakeweed / Modified Grassland Complex, Canyon Floor Complex, and Limestone Rim Complex, which are described below.

Grasslands in WACA often occur only as small patches amidst woodlands or shrublands. Only one grassland map class, Blue Grama and Mt. Muhly Group, was mapped. This map class combines a blue grama and mountain muhly association and occurs in 1% (240 ac/95 ha) of the entire map. Blue grama and mountain muhly typically dominate small meadows that are often adjacent to ponderosa pine, pinyon pine, and Utah juniper woodlands. Other grassland species also are common in the moister meadows of the Blue Grama and Mt. Muhly Group including muttongrass (*Poa fendleriana*), little bluestem (*Schizachyrium scoparium*), and squirreltail (*Elymus elymoides*). The rest of the grassland associations were mapped as the Snakeweed / Modified Grassland Complex. The map class Introduced Western Wheatgrass was not identified in the classification relevés; however, this map class does have a corresponding NVC herbaceous association (*Pascopyrum smithii* Herbaceous Vegetation) and was identified through the photointerpretation process.

Shrub herbaceous (steppe) vegetation associations are mapped in moderate distributions in the eastern section of the project. Shrub herbaceous vegetation associations form a steppe vegetation structure with a dominance of herbaceous cover and greater than ten percent shrub cover. Map class Rabbitbrush (*Ericameria nauseosa*) / Blue Grama Shrub Herbaceous Vegetation is the only shrub herbaceous association mapped; this association covers 2% (452 ac/180 ha) of the project area. The only other shrub herbaceous association (*Gutierrezia Sarothrae* Dwarf-Shrubland [provisional]) is mapped as part of the Snakeweed / Modified Grassland Complex.

Canyon Floor Complex occurs in the mesic canyon bottom of Walnut Canyon and its side canyons. This complex consists of linear polygons and covers less than 1% of the mapping area (150 ac/60 ha). Five associations and one alliance comprise the Canyon Floor Complex (three shrubland associations, one woodland association, one woodland alliance, and one forest association). Two of these associations also co-occur as upland associations in other map classes. For those associations that occur in the uplands and in the canyon bottom, the vegetation density and diversity tends to be higher in the canyon bottom habitat. The main tree and shrub species along canyon bottom consist of box elder (*Acer negundo*), Arizona walnut (*Juglans major*), Arizona rose (*Rosa arizonica*), Gambel oak, Douglas-fir, Rocky Mountain juniper (*Juniperus scopulorum*), stretchberry (*Forestiera pubescens* var. *pubescens*), roundleaf snowberry (*Symphoricarpos rotundifolius*), chokecherry (*Prunus virginiana*), and New Mexico locust (*Robinia neomexicana*). Riparian obligates include narrow-leaf cottonwood (*Populus angustifolia*), dogwood (*Cornus stolonifera*), and willow (*Salix* spp.). A diverse grass and forb community persists in the wet meadows, with fringed brome (*Bromus ciliatus*) often occurring as the main grass species. However, these grass and forb communities often occur in small patches and are included as some of the main understory species in the woodland and shrubland associations.

Limestone Rim Complex occurs on the rim of Walnut Canyon and its side canyons as well as on the limestone terrace canyon walls of Walnut Canyon. This complex covers 5% of the mapping area (950 ac/380 ha). Four associations comprise the Canyon Floor Complex (three woodland associations, one shrubland association). One of these associations also co-occurs as an upland association in another map class. The main tree species on the canyon rim is pinyon pine and it can co-occur with Utah juniper in the tree canopy, mountain mahogany (*Cercocarpus montanus*) and Stansbury Cliffrose (*Purshia stansburiana*) in the shrub layer, and blue grama in the herbaceous layer. A unique shrubland association commonly occurs on the limestone terraces on the north rim, which have a warm southern exposure, with common species including fernbush (*Chamaebatiaria millefolium*), barberry (*Mahonia fremontii*), banana yucca (*Yucca baccata*), cliffrose (*Purshia stansburiana*), and mountain mahogany (*Cercocarpus montanus*).

Snakeweed / Modified Grassland Complex occurs in disturbed areas in the northeastern section of the mapping area. This complex covers 12% (2,520 ac/1,020 ha) of the project area, with 90% of this complex occurring outside of the Monument. Four associations and one alliance comprise the Snakeweed / Modified Grassland Complex (two herbaceous association, one herbaceous alliance, one dwarf-shrubland, one shrubland association). Many of these associations resulted from chaining of trees, thought to increase the forage potential of the area. Gunnison's prairie dog (*Cynomys gunnisoni*) colonies also thrive in this area. The common shrubs and herbaceous species include a diverse array of native and non-native grass and shrub species including blue grama, rabbitbrush, fernbush, snakeweed (*Gutierrezia sarothrae*), horehound (*Marrubium vulgare*), western wheatgrass, little hogweed (*Portulaca oleracea*), and cliffrose. In these areas the native grasses often include blue grama, Fendler's threeawn (*Aristida purpurea*), and black grama (*Bouteloua eriopoda*). Non-native grasses in these areas include the invasive cheatgrass (*Bromus tectorum*) and western wheatgrass, a grass often used in reseeding efforts.

Vegetation map classes

The WACA vegetation mapping project used a total of 24 map classes: three geological classes, 13 vegetation classes and 8 Anderson Level II land-use classes (Anderson et al. 1976). The vegetation associations, Anderson land-use classes, and geologic exposures are related to the aerial photointerpretation map classes and are listed in Table 4. The final map classes were selected by CPRS, NPS and RSGIG personnel at a meeting held in May 2001. The units reflect the results of fieldwork, photointerpretation, and the NVC vegetation classification developed by the CPRS. The final map classes deviated from NVC associations when either 1) a NVC vegetation association could not be distinguished on the aerial photos as in the case of some of the dense woodland types, or 2) when special units were requested by Monument staff to aid with their management.

The final map class list for WACA contains four categories:

1) NVC associations represented by a unique photo-signature and topographic position.
2) Aggregations of NVC associations that together are represented by a unique signature.
3) Stands of vegetation that are not addressed by the NVC but are seen as management concerns for WACA and can be recognized on the aerial photography.
4) Geologic formations/exposures and land-use classes that are not addressed by the NVC.

Three of the map classes; Sparsely Vegetated Coconino Sandstone (map code 1), Sparsely Vegetated Kaibab Limestone (map code 2), and Sparsely Vegetated Intermittent Drainage Channel (map code 3); were developed as land use geologic classes. For the NVC associations *Pinus ponderosa* / *Bouteloua gracilis* Woodland and *Pinus ponderosa* / *Quercus gambelii* Woodland, two map classes are described for each association since the one-to-one relationship of NVC association to map class did not describe the ecological variation that we observed in the broad ecotonal landscape at WACA. *Pinus ponderosa* / *Bouteloua gracilis* Woodland is represented on the map as Ponderosa Pine / Mixed Graminoid Woodland Complex (map code 15) and Ponderosa Pine – Pinyon Pine – Juniper / Blue Grama Woodland (map code 12). Ponderosa Pine / Mixed Graminoid Woodland Complex shows the homogenous ponderosa pine canopy and Ponderosa Pine – Pinyon Pine – Juniper / Blue Grama Woodland shows a mixed ponderosa pine, pinyon pine, and juniper canopy. *Pinus ponderosa* / *Quercus gambelii* Woodland is represented on the map as Ponderosa Pine / Gambel Oak Woodland (map code 14) and Ponderosa Pine – Pinyon Pine – Juniper / Gambel Oak Woodland (map code 13), where Ponderosa Pine / Gambel Oak Woodland shows a pure ponderosa pine canopy and Ponderosa Pine – Pinyon Pine – Juniper / Gambel Oak Woodland shows a mixed ponderosa pine, pinyon pine, and juniper canopy.

Table 4. WACA map classes and their NVC components

Map Code	Map class	Associated NVC Plant Associations
1	Sparsely Vegetated Coconino Sandstone	none (Land Cover Class)
2	Sparsely Vegetated Kaibab Limestone	none (Land Cover Class)
3	Sparsely Vegetated Intermittent Drainage Channel	none (Land Cover Class)
4	Blue Grama – Mt. Muhly Grassland Group	*Bouteloua gracilis* Herbaceous Vegetation, *Muhlenbergia montana* Herbaceous Vegetation
5	Introduced Western Wheatgrass Grassland	*Pascopyrum smithii* Herbaceous Vegetation (described during photointerpretation process)
6	Common Horehound - Prairie Dog Town	none (described during photointerpretation process)
7	Snakeweed / Modified Grassland Complex	*Aristida purpurea* Herbaceous Vegetation, *Bromus (tectorum, rubens)* Semi-natural Herbaceous Alliance, *Bouteloua eriopoda* Semi-desert Herbaceous Vegetation, *Ericameria nauseosa - Gutierrezia sarothrae* Shrubland (local assemblage), *Gutierrezia sarothrae* Modified Dwarf-shrubland [provisional]
8	Rabbitbrush / Blue Grama Shrub Herbaceous Vegetation	*Ericameria nauseosa / Bouteloua gracilis* Shrub Herbaceous Vegetation
9	Limestone Rim Complex	*Pinus edulis – (Juniperus* spp.*) / Cercocarpus montanus* Woodland, *Pinus edulis –(Juniperus osteosperma) / Purshia stansburiana* Woodland, *Pinus edulis – (Juniperus osteosperma) / Bouteloua gracilis* Woodland, *Chamaebatiaria millefolium - (Mahonia fremontii) – Yucca baccata* Limestone Terrace Shrubland [provisional]
10	Canyon Floor Complex	*Acer negundo / Forestiera pubescens – Symphoricarpos rotundifolius* Temporarily Flooded Shrubland (local assemblage), *Quercus gambelii / Robinia neomexicana / Symphoricarpos rotundifolius* Shrubland, *Juniperus scopulorum* Woodland Alliance, *Pseudotsuga menziesii / Quercus gambelii* Forest, *Pinus ponderosa / Quercus gambelii* Woodland, *Chamaebatiaria millefolium – Forestiera pubescens* Shrubland (local assemblage)
11	Pinyon Pine - Utah Juniper / Blue Grama Woodland	*Pinus edulis – (Juniperus osteosperma) / Bouteloua gracilis* Woodland, *Juniperus osteosperma* Woodland Alliance
12	Ponderosa Pine - Pinyon Pine - Juniper / Blue Grama Woodland	*Pinus ponderosa – (Pinus edulis – Juniperus osteosperma) / Bouteloua gracilis* Woodland
13	Ponderosa Pine - Pinyon Pine - Juniper / Gambel Oak Woodland	*Pinus ponderosa – (Pinus edulis – Juniperus osteosperma) / Quercus gambelii* Woodland
14	Ponderosa Pine / Gambel Oak Woodland	*Pinus ponderosa / Quercus gambelii* Woodland
15	Ponderosa Pine / Mixed Graminoid Woodland Complex	*Pinus ponderosa / Bouteloua gracilis* Woodland, *Pinus ponderosa / Muhlenbergia montana* Woodland
16	Douglas-fir / Gambel Oak Forest	*Pseudotsuga menziesii / Quercus gambelii* Forest
17	Rural Residential	- none (Anderson Land Use class)
18	Ranch Developments	- none (Anderson Land Use class)
19	NPS Facilities	- none (Anderson Land Use class)
20	Utility Corridors	- none (Anderson Land Use class)
21	Transportation Routes	- none (Anderson Land Use class)
22	Pastures	- none (Anderson Land Use class)
23	Reservoirs	- none (Anderson Land Use class)
24	Stock Tanks and Dams	- none (Anderson Land Use class)

Each map class for WACA can be crosswalked to their NVC association using the aggregations described below:

One Map Class to One Plant Association
These map classes were developed by directly translating a NVC vegetation association into a map class onto the aerial photography.

Map Code — Map Class
NVC Plant Association

8 Rabbitbrush / Blue Grama Shrub Herbaceous Vegetation
Ericameria nauseosa / Bouteloua gracilis Shrub Herbaceous Vegetation

12 Ponderosa Pine - Pinyon Pine - Juniper / Blue Grama Woodland
Pinus ponderosa – (Pinus edulis – Juniperus osteosperma) / Bouteloua gracilis Woodland

13 Ponderosa Pine - Pinyon Pine - Juniper / Gambel Oak Woodland
Pinus ponderosa – (Pinus edulis – Juniperus osteosperma) / Quercus gambelii Woodland

14 Ponderosa Pine / Gambel Oak Woodland
Pinus ponderosa / Quercus gambelii Woodland

16 Douglas-fir / Gambel Oak Forest
Pseudotsuga menziesii / Quercus gambelii Forest

Multiple Associations-to-One Map Class

NVC associations and local assemblages identified in the aerial photography were too intermixed to identify as unique photosignatures. NVC associations were aggregated with ecologically similar NVC associations to form mosaics.

Map Code — Map Class
NVC *Plant Association/Alliance*

4 Blue Grama – Mt. Muhly Grassland Group
Bouteloua gracilis Herbaceous Vegetation
Muhlenbergia montana Herbaceous Vegetation

7 Snakeweed / Modified Grassland Complex
Aristida purpurea Herbaceous Vegetation
Bromus (tectorum, rubens) Semi-natural Herbaceous Alliance
Bouteloua eriopoda Semi-desert Herbaceous Vegetation
Ericameria nauseosa - Gutierrezia sarothrae Shrubland (local assemblage)
Gutierrezia sarothrae Modified Dwarf-shrubland [provisional]

9 Limestone Rim Complex

Pinus edulis – (Juniperus spp.*) / Cercocarpus montanus* Woodland
Pinus edulis –(Juniperus osteosperma) / Purshia stansburiana Woodland
Pinus edulis – (Juniperus osteosperma) / Bouteloua gracilis Woodland
Chamaebatiaria millefolium - (Mahonia fremontii) – Yucca baccata Limestone Terrace Shrubland [provisional]

10 Canyon Floor Complex

Acer negundo / Forestiera pubescens – Symphoricarpos rotundifolius Temporarily Flooded Shrubland (local assemblage)
Quercus gambelii / Robinia neomexicana / Symphoricarpos rotundifolius Shrubland
Juniperus scopulorum Woodland Alliance
Pseudotsuga menziesii / Quercus gambelii Forest
Pinus ponderosa / Quercus gambelii Woodland
Chamaebatiaria millefolium – Forestiera pubescens Shrubland (local assemblage)

15 Ponderosa Pine / Mixed Graminoid Woodland Complex

Pinus ponderosa / Bouteloua gracilis Woodland
Pinus ponderosa / Muhlenbergia montana Woodland

Park Special Map Classes

Only one vegetation map class at WACA is considered a park special. This map class was developed based on photointerpretation observation data.

Map Code	Map Class NVC *Plant Association*
5	Introduced Western Wheatgrass Grassland *Pascopyrum smithii* Herbaceous Vegetation

Aerial photograph interpretation

RSGIG interpretation of the aerial photographs for WACA relied heavily on substrate and landscape position. The usual aids to interpretation, color, shape, and texture, were less helpful in this case, partly because the aerial photos were flown in October when grasses were dormant and long tree shadows obscured the forest floor. A brief description of each map class follows. The number in parentheses indicates the map code. A more detailed, illustrated guide to the map classes appears in Appendix G.

<u>Sparsely Vegetated Coconino Sandstone</u> (1)

Coconino sandstone is intermittently exposed near the bottom of Walnut Canyon. It is a massive, cross-bedded sandstone whose outcrops are pale gray in color or white on the aerial photos. The only vegetation that occurs on outcrops is scattered patches of lichens and mosses, and a few vascular plants supported in occasional crevices.

<u>Sparsely Vegetated Kaibab Limestone</u> (2)

The majority of the walls of Walnut Canyon are vegetated Kaibab limestone. Small areas of sparsely vegetated limestone occur intermittently throughout the canyon in areas where the rock is vertical and unbroken. Kaibab limestone is easily distinguished from the Coconino sandstone because the limestone occurs in ledges and layers 2-6 ft (0.7-2 m) thick, giving the photosignature a striated appearance. This type was mapped where individual plants were too small or too scattered to see on the aerial photos and the dominant signature was the white of the bedrock.

<u>Sparsely Vegetated Intermittent Drainage Channel</u> (3)

Although water flows only rarely through Walnut Canyon, some areas of bare soil persist on the canyon floor. On the aerial photos these areas appear unvegetated, although they may support ephemeral communities of annual plants that were dormant at the time the photos were taken.

<u>Blue Grama - Mountain Muhly Grassland Group</u> (4)

Although patches of this type occur in the disturbed northeastern part of the mapping area (see map code 5), they cannot reliably be separated from the introduced grasslands on the aerial photos. Therefore, this type was only mapped in the undisturbed ponderosa pine woodlands, where it is a rare type occurring only in small patches along swales and in the larger woodland openings.

<u>Introduced Western Wheatgrass Grassland</u> (5)

We identified this map class in two areas based on fieldwork. It has a uniform, smooth signature and occurs in areas where the original vegetation was removed, then seeded with western wheatgrass.

<u>Common Horehound – Prairie Dog Town</u> (6)

This map unit was found to occur in one relatively large area in the northeast quadrant of the project area. This area was likely impacted both from past agricultural and land-management activity (mainly chaining, grazing, and re-seeding) and recent prairie dog activity. The continual impact to ground caused by burrowing likely contributed to the abundance of weedy non-native plants in area, especially common horehound. This class is considered a local, project specific type and is recognized on the aerial photos by the white stipple pattern of the prairie dog burrows and the smooth, bright texture of the weedy plants.

<u>Snakeweed / Modified Grassland Complex</u> (7)

This map class describes a large area in the northeastern part of the mapping area where the original pinyon-juniper woodland was chained and the ground seeded with a mix of native and introduced grasses. Very small areas of original vegetation survived this treatment, but cannot be reliably distinguished on the aerial photos. The complex photosignature reflects the disturbed, patchy nature of the vegetation.

<u>Rabbitbrush / Blue Grama Shrub Herbaceous Vegetation</u> (8)
This is the native grassland type, occurring in broad open park-like environments within the pinyon-juniper woodlands in the eastern half of the project area. It has been somewhat modified through grazing, which has caused rabbitbrush to increase in density. Although the color is similar to the grassland map classes, the texture is grittier due to the presence of shrubs.

<u>Limestone Rim Complex</u> (9)
This map class represents a complex of unique shrubland and woodland associations that are restricted to the south-facing slopes of Walnut Canyon, expanding onto the north-facing slopes at the broader east end of the canyon. Many of the species are characteristic of limestone soils, such as fernbush (*Chamaebatiaria millefolium*), barberry (*Mahonia fremontii*), banana yucca (*Yucca baccata*), cliffrose (*Purshia stansburiana*), and mountain mahogany (*Cercocarpus montanus*). The photosignature is varied, but dominated by the white of the underlying limestone. The vegetation appears as brownish red specks and patches.

<u>Canyon Floor Complex</u> (10)
The floor of Walnut Canyon is made up of a complex mosaic of several deciduous and grassland associations. The associations mostly occur in patches too small to map, so it was necessary to lump them in a mosaic. The mosaic includes woodlands of cottonwood (*Populus angustifolia*) and box elder (*Acer negundo*), Gambel oak thickets, and stands of deciduous shrubs such as chokecherry (*Prunus virginiana*) and wild rose (*Rosa arizonica*). Small upland stands of Gambel oak occur south of the canyon; because there is no separate Gambel oak map class, these stands were lumped with those occurring in the canyon.

<u>Pinyon Pine - Utah Juniper / Blue Grama Woodland</u> (11)
Walnut Canyon occupies a transition zone between low-elevation pinyon-juniper woodlands and the ponderosa pine woodlands that cover much of the Coconino Plateau. The eastern part of the mapping area was originally mostly this map class, although much of the original woodland was removed to improve grazing. A significant stand of old-growth pinyon-juniper occurs on basalt substrates on the northeastern face of Anderson Mesa. This type is recognizable on the aerial photos because of the short stature of the trees and the dull, dark color of the tree crowns.

<u>Ponderosa Pine - Pinyon Pine - Juniper / Blue Grama Woodland</u> (12)
This type forms a transition zone between the pinyon-juniper woodlands in the eastern half of the project area and the ponderosa pine woodlands in the western half. It is best developed southeast of the confluence of Cherry Canyon and Walnut Canyon.

<u>Ponderosa Pine - Pinyon Pine - Juniper / Gambel Oak Woodland</u> (13)
This type forms a transition zone between the pinyon-juniper woodlands in the eastern half of the project area and the ponderosa pine woodlands in the western half. It occurs mainly in the moister draws of the canyon floors and walls.

<u>Ponderosa Pine / Gambel Oak Woodland</u> (14)
Some of the best-developed examples of this map class occur south of Walnut Canyon in the western part of the project area, especially around the base of Anderson Mesa.

Ponderosa Pine / Mixed Graminoid Woodland Complex (15)
Much of the ponderosa pine woodland north of Walnut Canyon is this type, although scattered stems and copses of Gambel oak are scattered throughout. In general, this type of woodland has a more open canopy that allows sun-loving blue grama and mountain muhly to grow.

Douglas-fir / Gambel Oak Woodland (16)
The steep, north-facing walls of Walnut Canyon and its major tributaries support stands of Douglas fir. Gambel oak is the only species that occurs consistently in the understory.

Rural Residential (17)
Rural residential areas include scattered homes as well as denser subdivisions.

Ranch Developments (18)
This type was distinguished from Rural Residential primarily based on the isolation of buildings and their association with typical ranch features such as corrals and pastures.

NPS Facilities (19)
This map class includes the Visitor Center, the sewage ponds, and other aboveground developments associated with operation of the Monument.

Utility Corridors (20)
One telephone line cuts through the project area north of the visitor center. We identified this class in the field, and it appears on the photos as a narrow deforested corridor supporting grasses and a few shrubs.

Transportation Routes (21)
Mapped roadways include the main paved access roads as well as major USDA-FS and county dirt roads.

Pastures (22)
We delineated pastures based on their proximity to ranch developments, their distinctive smooth texture (rhizomatous grasses) and their linear boundaries (fence lines).

Reservoirs (23)
An historic reservoir site, now silted in, occupies a private inholding on the floor of Walnut Canyon. The stone dam structure is clearly visible, as is an area upstream of it that is periodically flooded and now supports a community of weedy annual plant species.

Stock Tanks and Dams (24)
These features are easily recognizable because of their characteristic location, size and shape.

GIS database and maps

The WACA GIS database consists of ten coverages, basemap imagery, and associated metadata in ArcInfo format and is archived on a CD (Appendix A) accompanying this report. The coverages are:

1) Accuracy assessment observation points.
2) Classification relevé points.
3) DOQQ and USGS Quad maps for Sunset Crater, Wupatki, and Walnut Canyon National Monuments.
4) DOQQ basemap imagery.
5) Flightline boundary for Sunset Crater, Wupatki, and Walnut Canyon National Monuments.
6) WACA park boundary.
7) Photointerpretative observation points.
8) Project boundary.
9) Seeps and springs.
10) Vegetation map clipped to the National Monument boundary.
11) Vegetation map for the entire project area. This main product coverage consists of 802 classified polygons covering a total area of approximately 20,732 ac (8,390 ha). Table 5 shows the total number of polygons and ha per map class in the project area.

A readme file (Appendix A) further describes these coverages.

A hard copy map was created of the vegetation coverage with a legend identifying the color of each map class. For clarity, the map code was printed only on polygons with an area greater than 5000 m^2 (0.5 ha). The hard copy map is presented in a folder sleeve (Appendix H).

Table 5. Map class occurrence in Walnut Canyon National Monument and environs.

Map Code	Map Class Common Names	Monument		Environs	
		Polygons	Hectares	Polygons	Hectares
1	Sparsely Vegetated Coconino Sandstone	27	22	11	8
2	Sparsely Vegetated Kaibab Limestone	10	4	1	0
3	Sparsely Vegetated Intermittent Drainage Channel	1	1	3	3
4	Blue Grama - Mt. Muhly Grassland Group	12	4	72	88
5	Introduced Western Wheatgrass Grassland	1	0.4	11	6
6	Common Horehound - Prairie Dog Town			2	20
7	Snakeweed / Modified Grassland Complex	10	41	28	978
8	Rabbitbrush / Blue Grama Shrub Herbaceous Vegetation	13	15	56	169
9	Limestone Rim Complex	34	239	32	145
10	Canyon Floor Complex	39	48	23	13
11	Pinyon Pine - Utah Juniper / Blue Grama Woodland	35	422	90	1721
12	Ponderosa Pine - Pinyon Pine - Juniper / Blue Grama Woodland	43	151	98	701
13	Ponderosa Pine - Pinyon Pine - Juniper / Gambel Oak Woodland			28	148
14	Ponderosa Pine / Gambel Oak Woodland	22	80	35	686
15	Ponderosa Pine / Mixed Graminoid Woodland Complex	30	300	40	2023
16	Douglas-fir / Gambel Oak Forest	29	129	13	48
17	Rural Residential			15	9
18	Ranch Developments			5	8
19	NPS Facilities	3	1		
20	Utility Corridors	2	0.3	3	4
21	Transportation Routes	3	11	10	57
22	Pastures			15	78
23	Reservoirs	1	4		
24	Stock Tanks and Dams			17	4
	Total	**315**	**1,472**	**597**	**6,910**

Accuracy assessment

In the 2001 sampling season, 227 accuracy assessment observations were included in the reference data out of the total 270 observations collected. We eliminated 43 observations since they represented duplicate observations in polygons in the final vegetation map. In these duplicate cases, we selected the observation that assessed the largest area of the polygon as the data to be used in the accuracy assessment analysis. For 2002, we added 126 additional accuracy assessment observations to the reference data making a combined total of 353 reference data points (Figure 13). Information recorded for each accuracy assessment observation is maintained in an MS Access database with its corresponding metadata and is located on the project CD (Appendix A). We assigned accuracy assessment observations that did not match any map classes as "other" in the reference data. This value and map classes 3, 17, 22, and 23 were not included in calculation of the error statistics in order to satisfy the assumptions for calculating the Kappa statistic (Carletta 1996). However, these classes we retained on the contingency table, see Table 7, 8, and 9. For the final accuracy assessment analysis, the total number of reference data points used to calculate overall exact match accuracy was 337, acceptable accuracy was 347, and understandable accuracy was 352. The final number of reference data points analyzed for each map class was representative of the relative percent cover of each map class except for map classes with a high percentage of occurrences on private land (i.e. land use classes). In these cases, the number of reference points sampled was less than the number suggested for the accuracy assessment analysis (Table 1).

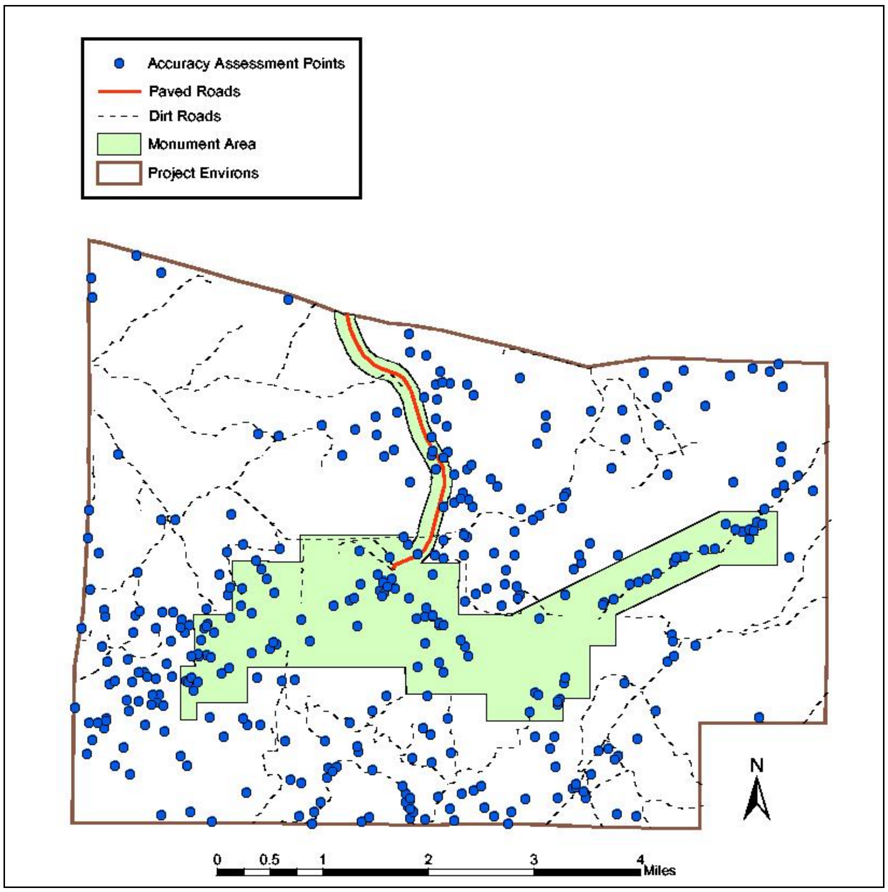

Figure 13. Location of accuracy assessment observations for the 2001 and 2002 combined reference data set.

Evaluation of the performance of each map class provides insight on map error. For each map class we report below the criteria at which the classes met the standard of 80% or greater for commission and omission accuracy (Table 6).

Table 6. WACA map class performance.

Map Code	Map Class	Commission Accuracy, (Criteria and %)	Omission Accuracy, (Criteria and %)	Comments
1	Sparsely Vegetated Coconino Sandstone	Acceptable 94%	Exact 83%	This type is considered adequate as mapped.
2	Sparsely Vegetated Kaibab Limestone	Acceptable 100%	Acceptable 100%	This type is considered adequate as mapped.
3	Sparsely Vegetated Intermittent Drainage Channel	N/A	N/A	Only two accuracy assessment observations of the total six polygons where sampled due to the inaccessibility of polygons on the canyon floor. All of the accuracy assessment observations were misidentified, resulting in the inability to rank commission and omission error. This map class was misclassified in both cases as Blue Grama – Mt. Muhly Grassland Group and as Canyon Floor Complex.
4	Blue Grama – Mt. Muhly Grassland Group	Exact 80%	Understandable 91%	When labeled incorrectly, this class was often confused with Snakeweed / Modified Grassland Complex or Rabbitbrush/Blue Grama Shrub Herbaceous Vegetation (omission error).
5	Introduced Western Wheatgrass Grassland	Acceptable 83%	Understandable 100%	When labeled incorrectly, this class was confused with Pinyon Pine-Utah Juniper/Blue Grama or Blue Grama – Mt. Muhly Grassland Group (omission error).
6	Common Horehound – Prairie Dog Town	Understandable 100%	Exact 100%	Only two polygons of this map class are on the vegetation map and both of these polygons were sampled. One polygon was misinterpreted as a Snakeweed/Modified Grassland Complex (commission error).
7	Snakeweed/Modified Grassland Complex	Understandable 95%	Understandable 95%	When labeled incorrectly, this class was often confused with the native community of Blue Grama – Mt. Muhly Grassland Group and Rabbitbrush / Blue Grama Shrub Herbaceous Vegetation (commission and omission error).

Map Code	Map Class	Commission Accuracy, (Criteria and %)	Omission Accuracy, (Criteria and %)	Comments
8	Rabbitbrush / Blue Grama Shrub Herbaceous Vegetation	Understandable 89%	Understandable 93%	On the map this class was misclassified as Snakeweed/Modified Grassland Complex (omission error). In the field, areas where this class was found were mapped as Blue Grama – Mt. Muhly Grassland Group (commission error).
9	Limestone Rim Complex	Understandable 96%	Understandable 92%	This class was misclassified as Pinyon Pine – Utah Juniper / Blue Grama Woodland and Ponderosa Pine – Pinyon Pine – Juniper / Blue Grama Woodland (commission and omission error).
10	Canyon Floor Complex	Acceptable 96%	Understandable 100%	On the map this class was misclassified as Rabbitbrush / Blue Grama Shrub Herbaceous Vegetation, Sparsely Vegetated Coconino Sandstone, and Blue Grama – Mt. Muhly Grassland Group (omission error).
11	Pinyon Pine – Utah Juniper / Blue Grama Woodland	Acceptable 80%	Understandable 76%	This type was often misclassified on the map as Limestone Rim Complex, Ponderosa Pine – Pinyon Pine – Juniper / Blue Grama, and Ponderosa Pine – Pinyon Pine – Juniper / Gambel Oak Woodland (omission error).
12	Ponderosa Pine – Pinyon Pine – Juniper / Blue Grama Woodland	Understandable 93%	Understandable 97%	This map class was misidentified as Ponderosa Pine / Mixed Graminoid Woodland Complex and Limestone Rim Complex (omission error) and misclassified as Pinyon Pine – Utah Juniper / Blue Grama Woodland and Ponderosa Pine - Pinyon Pine – Juniper / Gamble Oak Woodland (commission error).
13	Ponderosa Pine – Pinyon Pine – Juniper / Gambel Oak Woodland	Understandable 90%	Understandable 100%	This map class is often misclassified on the map as Pinyon Pine – Utah Juniper / Blue Grama Woodland (omission error) and in the field areas where it was found were misidentified as Ponderosa Pine / Gambel Oak Woodland (commission error).

Map Code	Map Class	Commission Accuracy, (Criteria and %)	Omission Accuracy, (Criteria and %)	Comments
14	Ponderosa Pine / Gambel Oak Woodland	Understandable 93%	Understandable 90%	This map class was often confused with Douglas-fir / Gambel Oak Forest (commission error) and Ponderosa Pine – Pinyon Pine – Juniper / Gambel Oak (omission error).
15	Ponderosa Pine / Mixed Graminoid Woodland Complex	Acceptable 85%	Acceptable 88%	This type is considered adequate as mapped.
16	Douglas-fir / Gambel Oak Forest	Acceptable 85%	Exact 87%	This type is considered adequate as mapped.
17	Rural Residential	N/A	N/A	Only one accuracy assessment observation was collected in this map class due to restricted access. The one polygon was misclassified on the map as Stock Tanks and Dams.
18	Ranch Developments	Exact 100%	Exact 100%	This type is considered adequate as mapped.
19	NPS Facilities	Acceptable 100%	Exact 100%	This type is considered adequate as mapped.
20	Utility Corridors	Exact 100%	Exact 100%	This type is considered adequate as mapped.
21	Transportation Routes	Acceptable 86%	Acceptable 100%	This type is considered adequate as mapped.
22	Pastures	Understandable 60%	Acceptable 100%	This type was often confused with Blue Grama – Mt. Muhly Grassland Group and Rabbitbrush / Blue Grama Shrub Herbaceous Vegetation (commission error).
23	Reservoirs	N/A	N/A	This map class had only one polygon on the entire vegetation map. This reservoir is located on private land and was not sampled due to restricted access to this land.
24	Stock Tanks and Dams	Acceptable 80%	Acceptable 80%	This type is considered adequate as mapped.

Standard analysis of map accuracy criteria 5, exact match category, suggested that overall accuracy was low (50.0%; 90% confidence interval of 47.0% to 53.0%) and a Kappa index of 45.3% (Table 7). For criteria 4 acceptable error, accuracy of the map is 69.2% (90% confidence interval of 64.1% and 71.8%) and Kappa index of 66.7% (Table 8). Criteria 3 (levels 5, 4 and 3 combined), understandable error, accuracy is 96.9 % (90% confidence interval of 95.6% and 98.2%) and a Kappa index of 93.9% (Table 9). Omission and commission accuracies for each individual map class, including two-tailed, 90% confidence intervals, are also shown for each in individual contingency table.

Table 7. Accuracy assessment contingency table (criteria 5, exact match) and statistical analysis of reference data with map class data.

		Reference Data (Field Accuracy Assessment Observations)																								Total	Commission Error	90% Confidence Intervals	
	Map Code*	Other*[1]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	N	(% Correct)	-	+
Map Class Data	1	1	10	1							1	4	1														18	55.6	36.9	72.8
	2		1	1							1		1														4	25.0	5.7	64.4
	3				0	1						1															2	N/A	N/A	N/A
	4					24			1				3	2													30	80.0	65.7	89.3
	5					2	1						3														6	16.7	3.8	50.2
	6							1	1																		2	50.0	12.1	87.9
	7					9			3	6			1														19	15.8	6.5	33.6
	8	2				10	1		2	3	1	5	2			2											28	10.7	4.4	24
	9										13		6			5	2	1									27	48.1	33.2	63.4
	10	2	1						1		2	21	2														29	72.4	57.3	83.7
	11					4			1	1	2		20			1							1				30	66.7	51.7	78.9
	12	1				2				1		1	6	13	4	2											30	43.3	29.6	58.1
	13					1					3	3	7	1	1	2	1										19	5.3	1.2	20.5
	14	1				1						1	2	3	8	8	3	3									30	26.7	15.7	41.5
	15	1				1					1		3	5	1		16										28	57.1	41.8	71.2
	16										1	1				4		20									26	76.9	61.2	87.6
	17																		0							1	1	N/A	N/A	N/A
	18																			1							1	100	27	100
	19													1							2						3	66.7	25.4	92.2
	20																					3					3	100	52.6	100
	21					1			1			1				1							3				7	42.9	18.6	71.1
	22					3				2														0			5	N/A	N/A	N/A
	23																								0		0	N/A	N/A	N/A
	24								1				1													3	5	60.0	27.2	85.7
Total	N	8	12	2	0	59	2	1	11	13	25	38	58	31	16	17	23	23	0	1	2	3	4	0	0	4	**Total Sampling Points: 337*[2]** **Total Correct: 167** **Overall Accuracy: 50.0%** **Kappa Index: 45.3%** **90% Confidence Interval: -47%, +53%**			
Omission Error	(% Correct)	N/A	83.3	50.0	N/A	40.7	50.0	100	27.3	23.1	52.0	55.3	34.5	41.9	.63	47.1	69.6	87	N/A	100	100	100	75.0	N/A	N/A	75.0				
90% Confidence Intervals	-	N/A	60.1	12.1	N/A	30.8	12.1	27.0	11.5	9.6	36.2	42.1	25.1	28.6	1.4	29	52.4	71.5	N/A	27.0	42.5	52.6	35.6	N/A	N/A	52.6				
	+	N/A	94.3	87.9	N/A	51.4	87.9	100	52.0	45.8	67.4	67.7	45.2	56.6	23.7	66	82.6	94.7	N/A	100	100	100	94.2	N/A	N/A	100				

*[1] Other was recorded in cases where none of the map classes available adequately described the vegetation

*[2]Total Sampling Points excludes undescribed (map class other), land cover, and land use classes (map classes 3, 17, 22, and 23) that do not satisfy the Kappa statistic assumption

* See Table 5 for list of map codes and labels.

Table 8. Accuracy assessment contingency table (criteria 4, acceptable accuracy) and statistical analysis of reference data with map class data.

		Reference Data (Field Accuracy Assessment Observations)																									Total	Commission Error	90% Confidence Intervals	
	Map Code*	Other*[1]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	N	(% Correct)	-	+
Map Class Data	1	1	16										1														17	94.1	71.4	21.5
	2			4																							4	100	59.7	100
	3				0	1						1															2	N/A	N/A	N/A
	4					27			1				2														30	90.0	77.4	95.9
	5					1	5																				6	83.3	49.8	96.2
	6							1	1																		2	50.0	12.1	87.9
	7					8			4	6			1														19	21.1	9.8	39.5
	8	1				3	2		4	13	1	2	1	1													26	50.0	31.9	61.6
	9										16		4	4	2	1											28	57.1	43.6	73.2
	10		1						2			26															27	96.3	76.7	95.8
	11					2			1		1		24	1		1											30	80.0	65.7	89.3
	12					2				1		1	5	19		2											29	65.5	50.2	78.1
	13					1					2	3	7		5		1										19	26.3	13.4	45.1
	14					1						1	2	3		18	2	2									29	62.1	45.1	73.3
	15	1				1					1		3		1		22										26	84.6	63.6	88.5
	16											1				3		22									26	84.6	69.8	92.9
	17																		0							1	1	N/A	N/A	N/A
	18																			1							1	100	27	100
	19																				3						3	100	52.6	100
	20																					3					3	100	52.6	100
	21					1																	6				7	85.7	54.7	96.7
	22					3				1														1			5	20.0	45.6	65.5
	23																								0		0	N/A	N/A	N/A
	24												1													4	5	80.0	43.5	95.4
Total	N	3	17	4	0	51	7	1	13	21	21	35	51	28	8	25	25	24	0	1	3	3	6	1	0	5	**Total Sampling Points: 347*[2]**			
Omission Error	(% Correct)	N/A	94.1	100	N/A	52.9	71.4	100	30.8	61.9	76.2	74.3	47.1	67.9	62.5	72	88	91.7	N/A	100	100	100	100	100	N/A	80.0	**Total Correct: 240** **Overall Accuracy: 69.2%**			
90% Confidence Intervals	-	N/A	77.4	59.7	N/A	41.6	40.9	27.0	14.6	44.1	58.5	60.7	36.0	52.3	34.8	55.7	73.5	77.7	N/A	27.0	52.6	52.6	68.9	27.0	N/A	43.5	**Kappa Index: 66.7%**			
	+	N/A	98.7	100	N/A	64.0	90.0	100	53.5	77.0	87.9	84.4	58.4	80.2	83.9	84	95.1	97.2	N/A	100	100	100	100	100	N/A	95.4	**90% Confidence Interval: 64.1-%, 71.8+%**			

*[1] Other was recorded in cases where none of the map classes available adequately described the vegetation

*[2]Total Sampling Points excludes undescribed (map class other), land cover, and land use labels (map classes 3, 17, and 23) that do not satisfy the Kappa statistic assumption

* See Table 5 for list of map codes and labels.

Table 9. Accuracy assessment contingency table (criteria 3, understandable accuracy) and statistical analysis of reference data with map class data.

		Reference Data (Field Accuracy Assessment Observations)																									Total	Commission Error	90% Confidence Intervals	
	Map Code*	Other*[1]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	N	(% Correct)	-	+
Map Class Data	1	1	16										1														18	88.9	71.4	96.3
	2			4																							4	100	59.7	100
	3				2																						2	100	42.5	100
	4					30																					30	100	91.7	100
	5						6																				6	100	68.9	100
	6							2																			2	100	42.5	100
	7								18				1														19	94.7	73.8	96.6
	8									25	1		1	1													28	89.3	76	95.6
	9										26					1											27	96.3	85	99.2
	10											29															29	100	90.9	100
	11								1				29														30	96.7	86.4	99.3
	12									1				28		1											30	93.3	81.7	97.8
	13					1							1		17												19	89.5	86.3	100
	14					1							2			27											30	90	77.4	95.9
	15										1		3				24										28	85.7	71.1	93.4
	16																	26									26	100	90.6	100
	17																		1								1	100	27.0	100
	18																			1							1	100	27.0	100
	19																				3						3	43.3	52.6	100
	20																					3					3	100	52.6	100
	21																						7				7	100	72.1	100
	22					1				1														3			5	60.0	52.6	100
	23																								0		0	N/A	N/A	N/A
	24																									5	5	80.0	59.7	100
Total	N	1	16	4	2	33	6	2	19	27	28	29	38	29	17	29	24	26	1	1	3	3	7	3	0	4				
Omission Error	(% Correct)	N/A	100	100	100	90.9	100	100	94.7	92.6	92.9	100	76.3	96.6	100	93.1	100	100	100	100	433.3	100	100	100	N/A	100				
90% Confidence Intervals	-	N/A	85.5	59.7	42.5	79.3	68.9	42.5	79.5	79.9	80.6	77.4	63.5	85.9	72.7	81.2	89.9	90.6	27.0	27.0	52.6	52.6	72.1	27.2	N/A	43.5				
	+	N/A	100	100	100	96.3	100	100	98.8	97.5	97.6	95.9	85.7	99.2	96.5	97.7	100	100	100	100	100.0	100	100	85.7	N/A	95.4				

Total Sampling Points: 352*[2]
Total Correct: 341
Overall Accuracy: 96.9%
Kappa Index: 93.9%
90% Confidence Interval: 95.6-%, 98.2+%

*[1] Other was recorded in cases where none of the map classes available adequately described the vegetation

*[2]Total Sampling Points excludes the undescribed map class (other) since it does not satisfy the Kappa statistic assumption

* See Table 5 for map codes and labels.

5. DISCUSSION

The vegetation at WACA varies by elevation, has unique ecotonal associations, and includes diverse vegetation associations in the mesic canyons. These, in addition to limestone canyon terraces and modified, disturbed landscapes, represent some unique challenges in describing and mapping the landscape. The challenges to vegetation mapping at WACA are summarized below:

1) Vegetation associations are difficult to photointerpret in modified landscapes. We combined four vegetation associations and one alliance into a single map class (Snakeweed / Modified Grassland Complex) because the photointerpreter was unable to directly pick out each association within the highly variable landscape. These modified landscapes include native and non-native species inter-fingering into unique assemblages of herbaceous, shrub, and shrubby herbaceous vegetation. This map class occurs in a large portion of the northeastern section of the project boundary with few map polygons (12% of the total project area, 28 polygons). Many of the accuracy assessment observations within this disturbance type were assigned to native non-disturbed map classes. The vegetation may have changed during the interval between the aerial photography acquisition in 1996 and the photointerpretation in 1999-2002. Alternatively, the nature of the vegetation mosaic could not be distinguished at the 0.5 ha resolution with the aerial photographs, and as a result the polygons were sufficiently dissected.

2) Areas on the aerial photography that are masked by landscape features are difficult to photointerpret to the association level. This was especially true on the canyon walls and canyon bottoms where we lumped the vegetation into complexes of associations to create a map class. The photointerpreters were not able to delineate separate associations in areas that appeared as linear bands on the aerial photography, they were also likely under sampled due to poor accessibility. As the canyon bottoms and canyon walls appeared to be diverse, we think that with additional field sampling along the canyon bottoms, rims, and walls, additional NVC vegetation associations may be described for WACA. Phillips (1990) mapped the WACA riparian corridor with several different vegetation associations using the Brown and Lowe (1974) vegetation classification system in the canyon bottom. We suspect that this study can be used to augment the current vegetation map; however, new data collection would be important to attain due to the temporal sensitivity of the data. Accuracy assessment positioning was also challenging in these map classes, where polygons were often small and linear.

3) The number and variability of vegetation signatures sometimes made them difficult to distinguish and interpret consistently. Environmental factors such as moisture gradients, slope exposure, presence and density of exotic grasses and forbs, and soil diversity result in several photographic signatures for the grassland and some shrub and woodland classes. In many cases, broad ecotones between map classes resulted in the field crew selecting a single map class in areas where more than one map class was present within a single polygon. In these cases, the accuracy assessment field crew described the complexity of the polygon on the field sheet and often identified where more than one map class occurred within a single polygon. In cases where polygons appear to contain characteristics of two map classes, the

map classes may need to be merged to increase the map class accuracy. This happened most of the time at accuracy assessment observations where the tree cover was moderate and the grass or shrub cover was high.

4) Changes in the photointerpretative style between the preliminary map in 2001 and the final map in 2002 influenced the accuracy assessment results. Polygons that were assessed in 2001 often were significantly different in size and shape from the 2002 final vegetation map polygons. In some cases, the placement of the 2001 accuracy assessment observations that were assessed were not optimal for assessment of the 2002 final map. Funding limitations prevented us from completely redoing the accuracy assessment using the final vegetation map.

5) Small polygon sizes are difficult to confidently locate in the field. Twenty-eight percent of the polygons were delineated below the MMU. Although this level of detail provides extra information to the park on the distribution of the map classes, it makes accurate positioning within the polygon more difficult to achieve without sophisticated GPS processing and more field time to collect signal. This also increased the number of required polygons for accuracy assessment. For example, Canyon Floor Complex routinely occurs in small linear patches on the canyon floor of Walnut Canyon. These small polygons may have contributed to apparent misclassification of map classes during the accuracy assessment. We considered possible locational errors during the accuracy assessment analysis; however, it is likely that map users may also experience the same problems with determining exact locations.

6) The classification relevés (1999), photointerpretation observations (1999, 2000, and 2001), and accuracy assessment observations (2001 and 2002), may be measuring land cover characteristics that are different from those shown on the 1996 photography used for map creation. Land surface changes since the 1996 aerial photography acquisition could include trail development, increased recreational activities, non-native plant invasions, native plant increases or decreases, and changes in the riparian annual plant community composition associated with changing hydrologic regime in the canyon bottom. This is especially applicable to the USDA-FS lands surrounding the Monument that have evidence of recent modifications. Trees that were present in the aerial photography were subsequently removed, and were not present during the accuracy assessment. In addition, modified landscapes are sometimes easier to detect remotely using the aerial photography than on the ground. On the aerial photography the landscape appeared in some cases to be significantly different than the adjacent areas due to human modification of the landscape; however, when visited in the field, native species were prevalent and no visible evidence of recent human modification was obvious. This different perception of modification most often resulted in confusion between Snakeweed / Modified Grassland Complex, Rabbitbrush / Blue Grama Shrub Herbaceous Vegetation, and Blue Grama – Mt. Muhly Grassland Group. Also, plants that were dormant when the aerial photography was flown in October 1996 were growing when the field data were collected in the summer of 1999, 2000, 2001, and 2002. This difference can cause ecologists in the field and photointerpreters to give the same area different names. These vegetation changes may occur frequently enough to cause misclassified polygons and therefore decrease the measured total accuracy assessment.

7) Because the aerial photos were flown late in the year, shadows created interpretation problems. Long shadows partially to completely obscured the understory communities and made it more difficult to discern the diagnostic understory stratum. Due to the long shadows, it was difficult to locate control points in the wooded parts of the mapping area for aerial photograph registration. This was true for both the aerial photography (October 1996) and the photography used to generate the DOQQ base maps (October 1997). Locating enough control points became very time-consuming. Acquiring new aerial photography and generating an orthophoto base map from that photography could avoid this problem. In addition, there would be no ground condition difference between the photos used for interpretation and the base map. Another advantage would be the age of this database. If new photography were used at the start of this project, the database's ground condition would be only three years old instead of six years old when the project was completed.

Vegetation classification and map class development

Two new alliances, three new associations, one provisional alliance and two provisional associations, and three unique Monument specific assemblages were newly defined during the course of this project. The remainder of the vegetation types were described primarily using existing NVC community classification. Although the woodland associations comprised over 80% of the mapping area, almost half of the diversity in associations was described in the shrubland and herbaceous formation classes. In all of the Shrubland, dwarf-shrubland, and herbaceous associations, each association described fell under a unique alliance description and all of the new, provisional, and local assemblages were also described in these formation classes. This diversity and uniqueness in shrubland, dwarf-shrubland, and herbaceous associations is in part an artifact of most previous data having been collected in forest and woodland formations and less data collected in the shrubland and herbaceous formations. With additional information collected in these formations on the Colorado Plateau, the NVC alliance and association designations may change. In addition, the provisional associations and local assemblages, if significantly described elsewhere, may eventually be included as confirmed associations within the NatureServe Explorer database.

Only six of the possible 23 associations and alliances described had one-to-one correspondence with a map class; the remaining associations and alliances were combined to form ecologically unique complexes of associations. Limited direct correspondence of the associations to the map classes was due to the complexity of associations on the canyon walls, canyon bottoms, and on disturbed lands, as well as limitations in photointerpreting grassland associations. For two map classes we were able to map additional vegetation community detail, currently designated as a phase of a NVC association, by mapping the broad ecotonal communities of mixed ponderosa pine (*Pinus ponderosa*), pinyon pine (*Pinus edulis*), and Utah Juniper (*Juniperus osteosperma*) with either blue grama (*Bouteloua gracilis*) or Gambel oak (*Quercus gambelii*) understories. These ecotonal areas we believed were ecologically significant and important to resource management.

Woodlands comprised the major part of the mapping effort. They gradate in the lower elevation uplands from pinyon pine and Utah juniper associations to the higher elevation ponderosa pine associations. The density of trees in these associations varies depending on land use history and fire regime. In some areas ponderosa pine form thick stands and could be considered a forest association with greater than 60% total canopy cover; however, these stand structures are not considered ecologically different at this time in the NVC and were maintained as woodland associations. Douglas-fir (*Pseudotsuga menziesii*) / Gambel oak forests were the only true forests described at WACA, due to the high density of the Douglas-fir canopy. Douglas-fir and Rocky Mountain juniper are common canyon bottom and north-facing cooler, moister plant associations. These associations, although commonly found at higher elevations elsewhere on the Colorado Plateau, persist in the cool moist canyons at WACA.

Although we described five shrublands and one dwarf-shrubland association during the course of this project, we could not directly map any of these associations. Many of the shrubland associations occurred on canyon walls and in highly transitional disturbed lands. Shrublands and Dwarf-Shrublands were included in the Limestone Rim Complex, Canyon Floor Complex, and Snakeweed / Modified Grassland Complex map classes.

Seven herbaceous associations, including all of our new associations and alliances, were described in the herbaceous formation class. However, only one of these associations was directly translated into a map class. The associations were not easily mapped due to the similarity in photosignatures between tightly inter-fingering associations in the disturbed areas. The herbaceous map class aggregates include the Snakeweed / Modified Grassland Complex and the Blue Grama – Mt. Muhly Grassland Group. The only directly translatable map class is Rabbitbrush / Blue Grama Shrub Herbaceous Vegetation, a shrub herbaceous association. Two additional map classes, Introduced Western Wheatgrass Grassland and Common Horehound - Prairie Dog Town, were identified as unique herbaceous vegetation assemblages during the photointerpretation process but were not observed during the relevé classification. However, these map classes were considered ecologically important and, as they were easily delineated by the photointerpreters, were included on the vegetation map.

The USGS-NPS vegetation mapping projects are designed to produce both a vegetation classification and a set of map classes. Typically, the NVC classification and the map classes are very similar, but sometimes there is not a strict one-to-one correspondence between them. Photographic interpretation centers around the ability to accurately and consistently delineate map classes based on complex signatures. Vegetation characteristics that can be seen on aerial photography are not necessarily the same as those apparent on the ground. Map verification work in the field aided enormously in developing the map classes and discerning the inherent variability of each photographic signature.

Accuracy Assessment

The USGS-NPS park mapping program has the standard of 80% overall map accuracy and for each class. Overall, the map meets this standard using the understandable accuracy criteria. Acceptable accuracy criteria accounted for a number of apparent misclassifications that may have occurred because of differences between the preliminary and final maps that could not be accounted for in the development of the 2001 sampling design. Understandable accuracy includes all acceptable errors as well as mistakes in interpretation in understory communities, which are often very sparse and difficult to distinguish in the photography. We believe the map is usable as long as the assessments for each individual map class are reviewed and kept in mind when the map is being used for management purposes. Most error in the map can be directly attributed to known sources and not to gross error in photointerpretation.

Aggregation of the main grassland and steppe map classes together (map classes 4, 7, 8 Blue Grama – Mt. Muhly Grassland Group, Snakeweed / Modified Grassland Complex, Rabbitbrush / Blue Grama Shrub Herbaceous Vegetation) would increase map accuracy. If these map classes were aggregated, it would improve the overall map accuracy to 76%, an increase of 7% using the acceptable criteria. However, this aggregation would not allow the user to distinguish between native or recently modified landscapes as well as between steppe and grassland communities. This aggregation would reduce the detail of the map; however, increase the map accuracy.

Applications

The vegetation map is ready for use with the knowledge that some of the map classes are below the desired 80% accuracy. These map classes may need to be aggregated depending on the desired accuracy needed for a particular project. Map classes can be aggregated to the NVC alliance level or to the lifeform.

This map will provide the baseline vegetation data that will support sound resource management of the park. As with other USGS-NPS park management programs, it is possible that this map will assist with many different aspects of planning activities, including fire management planning, habitat modeling, field sampling for threatened and endangered species, research of particular species and their habitats, education and interpretation, and trail maintenance. This study will also help to compare habitats across management boundaries and hopefully to assist in the joint-agency management of the lands studied in the project environs. Ultimately, the vegetation map will help to monitor impacts on vegetation health as well as the overall ecosystem health of the area.

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7. GLOSSARY

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This glossary refers to terms as they are used in USGS-NPS vegetation mapping projects. Some terms may not appear in this report.

7.5-Minute Quadrangle. Informally known as a 'quad' map. A USGS paper map product at 1:24,000 scale covering 7.5 minutes of latitude and 7.5 minutes of longitude. Features shown include elevation contours, roads, railroads, water bodies, buildings, urban developments, wooded cover, permanent ice fields, and wetlands. This is a basic layer of information for many ecological and natural resource applications. A digital version of a 7.5-minute quad is called a Digital Raster Graphic (DRG).

Accuracy. The closeness of results of observations, computations, or estimates to the true values or to values that are accepted as being true (ASP 1984). See also Error.

Accuracy Assessment (AA). The process of determining the thematic accuracy of the vegetation map. An unaffiliated ecologist tests map accuracy after the vegetation mapping and classification are complete. (Stadelmann et al. 1994).

Accuracy Assessment Point. A location where accuracy assessment data are collected. See "Producing rigorous and consistent accuracy assessment procedures" at http://biology.usgs.gov/npsveg/aa/aa.html for more information.

Aerial Photography. Photography taken from an airplane (not satellite) mounted with specially designed photographic equipment. Ideally, the lens and the film are parallel to the surface being photographed. A sequence of aerial photographs along a flight line will have a certain amount of overlap so that the photos can be viewed with a stereoscope. "Sidelap" refers to overlap between flight lines (ASP 1984). Print size is usually 9"x9" and are photos that may use true color or color infrared film.

Alliance. A physiognomically uniform group of associations sharing one or more diagnostic (dominant or indicator) species that usually occur in the uppermost stratum of the vegetation (FGDC 1997). This is the second finest level in the NVCS hierarchy.

Anderson Classification System.
A classification system developed for use with remote sensing systems in the 1970s adopted for the National Vegetation Classification to map cultural and water features (Anderson et al. 1976).

Level I	**Level II**
Urban or Built-up Land	Residential
	Commercial and Services
	Industrial
	Transportation, Communications, and Utilities
	Industrial and Commercial Complexes
	Mixed Urban or Built-up Land
	Other Urban or Built-up Land
Agricultural Land	Cropland and Pasture
	Orchards, Vineyards, and Ornamental Horticultural Areas

	Confined Feeding Operations
	Other Agricultural Lands
Water (non-vegetated portion)	
	Streams and Canals
	Lakes
	Reservoirs
	Bays and Estuaries
Barren Land	
	Dry Salt Flats
	Beaches
	Sandy Areas other than Beaches
	Strip Mines, Quarries, and Gravel Pits
	Transitional Areas
	Mixed Barren Lands

ArcInfo. A geographic information software used to view and analyze data.

Association. The finest level of the NVCS classification hierarchies. A physiognomically uniform group of stands of vegetation that share one or more diagnostic overstory and understory species. These elements occur as repeated patterns of assemblages across the landscape, and are generally found under similar habitat conditions (FGDC 1997).

Attribute (digital data). A numeric, text, or image data field in a relational database table (such as a GIS) that describes a spatial feature such as a point, line, polygon, or cell (ESRI 1994).

Automation. The process of entering data into a computer (see also Digitize).

Base map. The control to which all spatial data is georeferenced. Interpreted photo data are transferred to a base map to rectify and register the data. In this project the base maps are USGS DOQQs.

Bureau of Reclamation (USBR, BOR). A U.S. Department of Interior agency created in 1902 and charged with developing environmentally and economically sound irrigation and hydropower projects in 17 Western States. The Remote Sensing and GIS Group of the BOR manages a number of park projects for the USGS-NPS Vegetation Mapping Program.

Biological Resources Discipline (BRD). A USGS discipline housing the Center for Biological Informatics. The BRD's mission is to work with others to provide the scientific understanding and technologies needed to support the sound management and conservation of our Nation's biological resources. Formerly, the National Biological Service (NBS).

Center for Biological Informatics (CBI). A USGS Science Center. CBI serves as the operating agent for the National Biological Information Infrastructure. In addition, CBI manages the USGS-NPS Vegetation Mapping Program along with other national data collection programs that complement and strengthen its role within the NBII.

Class. The level in the NVCS hierarchies based on the structure of the vegetation. Class is determined by the relative percentage of cover and the height of the dominant, uppermost life forms (Grossman et al. 1998).

Classification Accuracy. How closely the map classes match the vegetation found on the landscape. This is determined by accuracy assessment protocols. See "Producing rigorous and consistent accuracy assessment procedures” at http://biology.usgs.gov/npsveg/aa/aa.html for more information.

Color Infrared (CIR) Film. A three-layer color film sensitized to green, red, and near-infrared portions of the spectrum. CIR films emphasize differences in infrared reflectance from surfaces and are some of the most useful aerial films currently available for use in agricultural and vegetation surveys. The images are sharper and have better contrast than conventional color photos because they are less susceptible to atmospheric light scattering. Furthermore, CIR has a high transmission component through green leaves, meaning that it can detect layers of leaves lower in the canopy. In true-color photography, the photosynthetic pigments within leaves quickly absorb visible light, and the film records information about nothing below the uppermost leaf layer. Color differences recorded on CIR film are used to differentiate among vegetation types. Generally, in spring and summer, healthy deciduous trees and other vegetation photographs as magenta or red, while healthy evergreens photograph more as a brownish red. CIR film can only be used in daylight.

Commission Accuracy. See Producer's Accuracy.

Community. An assemblage of species that co-occur in defined areas at certain times and have the potential to interact with one another (Grossman et al. 1998). In the NVCS, Association and Community are synonyms.

Community Element Global (CEGL). NatureServe's unique plant association coding system in their central biodiversity database; also known as Elcode.

Community Type. See Association or Type.

Complex. A group of associations that are not distinguishable from one another on aerial photography and so are grouped into a map class. Compare with Mosaic.

Confusion Matrix. See Contingency Table.

Contingency Table. A table that is used in accuracy assessment to determine the degree of misclassification that has occurred. The table compares the labels derived from accuracy assessment relevés to the labels derived from photointerpretation. Also referred to as Error Matrix, Confusion Matrix, or Misclassification Matrix.

Coordinate System. A reference system that represents horizontal and/or vertical locations and distances on a map. A geographic coordinate system is the latitude and longitude with respect to a reference spheroid. A local coordinate system is one that is not aligned with the Earth's surface. Most coordinate systems are based on projections of the earth's surface onto a plane. All spatial data in this project uses the Universal Transverse Mercator (UTM) coordinate system.

Cover. The area of ground covered by the vertical projection of the aerial parts of vegetation (FGDC 1997).

Cover Type. A designation based upon the plant species forming a plurality of composition within a given area (e.g., Oak-Hickory) (FGDC 1997). It is roughly equivalent to an Alliance in the NVCS classification hierarchy.

Coverage. A data theme in a geographic information system with vector and polygon topology and attribute data related to that topic. Also, the file format used by Arc/Info software for vector spatial data.

Cowardin Classification. A wetland classification system used as the FGDC standard for wetland classification (Cowardin et al. 1979).

Crosswalk. The relationship between the elements of two classification systems. For example, this project includes a crosswalk between Map Classes and units of the NVCS. In a database, the crosswalk is in a Lookup Table (LUT).

Cultural Vegetation. Vegetation planted or actively maintained by humans such as annual croplands, orchards, and vineyards. Contrast with Natural Vegetation.

Datum. A mathematical model that describes the shape of the earth. The earth is not a sphere but is rather an ellipsoid distorted by rotation about its axis, bulging at the equator and flattened at the poles. Because of the distribution of continents and seas, the distortion is not uniform around the globe and there are datums for different parts of the earth based on different measurements (Snyder 1982). The datum used by this project is NAD83.

Datum (horizontal-control). The position on the spheroid of reference assigned to the horizontal control of an area. A datum may extend over an entire continent or be limited to a small area (referred to as 'local datum'). This project used the North American Datum of 1983 (NAD83) (ASP 1984).

Density. Density is the relationship between the area covered by the vegetation and the total area of a polygon in which the community is found. The USGS-NPS Vegetation Mapping Program uses a series of arbitrarily defined density classes to separate vegetation units: Closed/Continuous > 60 %, Discontinuous 40-60%, Dispersed 25-40%, Sparse 10-25%, Rare 2-10%. Compare with Pattern and Height.

Diagnostic Species. A species generally considered to indicate (i.e., diagnose) a specific set of environmental conditions. For example, the presence of *Vaccinium stamineum* var. *stamineum* (gooseberry) beneath a canopy of chestnut oak, black oak, and Virginia pine indicates that the site is dry. The trees can inhabit a wide range of sites, wet to dry, but the gooseberry understory is the indicator of a drier habitat. Sometimes also called Indicator Species (FGDC 1997).

Dichotomous Field Key. A document that identifies plant associations or map classes on the basis of pairs of exclusive characteristics such as "forested" versus "non-forested". This key is an important product of each vegetation-mapping project. Also known as Vegetation Field Key and Vegetation Key.

Digital Orthophoto Quadrangle (DOQ). A USGS digital product derived from high altitude aerial photography. Each DOQ is rectified and registered to locations on the earth and covers the same area as a 7.5 minute quad. These are often used as base maps to register photointerpreted data. See also Quarter Quadrangle.

Digital Raster Graphic (DRG). A scanned image of a paper USGS topographic quadrangle map. The geographic information is georeferenced to the UTM projection with the same accuracy and datum as the original map. The minimum scanning resolution is 250 dots per in.

Digitize. The process of converting lines on a map or image into a computer file. The basic technique involves tracing a line with a device connected to a computer that sends a stream of x-y coordinates corresponding to the traced line into a computer file. Synonymous with Automation.

Division. The highest level in the NVCS hierarchy, separating the earth's surface into vegetated and non-vegetated categories (FGDC 1997). (See NVCS).

Dominance. The extent to which a given species or life form dominates in a community because of its size, abundance or cover. The ecological assumption is that dominant species can affect the fitness of associated species (FGDC 1997).

Dominant Life Form. An organism, group of organisms, or taxon that by its size, abundance, or coverage exerts significant influence upon an association's biotic and abiotic conditions (FGDC 1997).

Ecological Groups. Non-NVC categories of vegetation based on plant assemblages, physical environments, and dynamic processes useful for conservation planning. These groups are classified on total floristic composition, physiognomy (vertical structure), distribution (horizontal structure), physical environment (slope, rainfall), chemical variables (soil pH), and disturbance regimes. Some factors are difficult to measure directly, and must be inferred from knowledge of species ecology, spatial patterns, and ecological processes.

Edge Distortion. In reference to aerial photographs, lens distortion increases with distance from the center of the photograph. Because of this, photointerpreters work only with the center third of each aerial photograph.

Error. The numeric distance of results of observations, computations, or estimates from the values that are accepted as being true. Also refers to the misclassification of thematic data. Contrast with Accuracy.

Error Matrix. See Contingency Table.

Existing Vegetation. The plant species existing at a location at the present time. The USGS-NPS Vegetation Mapping Program classifies and maps existing vegetation. Contrast with Potential Vegetation.

Federal Geographic Data Committee (FGDC). Coordinates the development of the National Spatial Data Infrastructure (NSDI). The NSDI encompasses policies, standards, and procedures for agencies to produce and share geographic data. The 17 federal agencies that make up the FGDC are developing the NSDI in cooperation with state, local, and tribal governments, the academic community, and the private sector.

Field Reconnaissance. Preliminary field visits by photointerpreters and vegetation ecologists to gain an overview of the vegetation of the project area and how it relates to the NVC.

Flight Line. A line connecting the principal points of sequential vertical aerial photographs. Designated on the film as 'flight line number – photo number' (ASP 1984).

Floristics. The kinds, number and distribution of plant species in a particular area.

Formation. A level in the NVCS hierarchies that represents vegetation types sharing a definite physiognomy or structure within broadly defined environmental factors, relative landscape positions, or hydrologic regimes (Grossman et al. 1998).

Frequency. The number of occurrences of an item of interest.

Georeference. The process of converting a map or image into real-world coordinates. A non-georeferenced map or image is said to be in ‘digitizer-inches’ or ‘scannerinches', i.e., it has no real-world coordinates.

Geographic Information System (GIS). An organized database of geographically referenced information (ESRI 1994).

Global Positioning System (GPS). A system of satellites, ground receiving stations and handheld receivers that allow accurate location of features on the earth's surface. GPS receivers are used to locate field relevés, reconnaissance points, and accuracy assessment points.

Gradsect. Gradient directed transect sampling. The gradsect sampling design is intended to provide a description of the full range of biotic variability (e.g., vegetation) in a region by sampling along the full range of environmental variability. This approach is based on the distribution of vegetation along environmental gradients. Transects that contain the strongest environmental gradients in a region are selected in order to optimize the amount of information gained in proportion to the time and effort spent during the vegetation survey (Grossman et al. 1994).

Ground photograph. An image recorded with the photographer standing on the ground (See Aerial Photography).

Ground truth. The process of taking aerial photographs into the field to see how particular photographic signatures compare with the vegetation on the ground.

Group. The level in the NVCS hierarchies based on leaf characters and identified and named in conjunction with broadly defined macroclimatic types to provide a structural-geographic orientation (Grossman et al. 1998).

Habitat. The combination of environ-mental or site conditions and ecological processes influencing a plant community.
Habitat Type. 1. A collective term for all parts of the land surface supporting, or capable of supporting, the same kind of climax plant association (Daubenmire 1978). 2. An aggregation of land areas having a narrow range of environmental variation and capable of supporting a given plant association (Gabriel and Talbot 1984).

Hectare. A metric unit of measure equal to 10,000 m^2 or approximately 2.471 ac.

Height. Height of the overstory of a plant community. One of the physiognomic modifiers classified in the USGS-NPS Vegetation Mapping Program. Vegetation polygons are attributed by height class: < 0.5 m, 0.5-2 m, 2-5 m, 5-15 m, 15-35 m, 35-50 m, >50 m. Compare with Density and Pattern.

Indicator Species. See Diagnostic Species.

Infrastructure. Human-built systems that include structures such as roads and bridges, water supply systems, and electric, gas or telephone lines.

Integrated Taxonomic Information System (ITIS). A comprehensive, standardized reference for the scientific names, synonyms and common names for all the plants and animals of North America and the surrounding oceans. This database is accessible over the Internet (http://www.itis.usda.gov/). The PLANTS database is an important ITIS partner providing plant taxonomic information to ITIS.

Land Cover Classification.
A classification of the cultural, physical, and vegetation features that cover the earth, commonly used with remote sensing tech-

nology. The Anderson Classification System is a land cover/ land use classification. Vegetation classification is a subset of land cover classification.

Land Use Classification. A classification of the earth's surface that defines the human use the land is providing. Commonly used with remote sensing technology, and usually combined with land cover classification. Natural vegetation may be classified as "vacant", "forest", or "grazing".

Large-scale. Refers to a map or image with a large-scale denominator (e.g., 1:100,000). Large-scale maps cover a broad area, are usually low in detail, and images usually have low resolution (e.g., 30m per pixel).

Look-Up Table (LUT). A computer file that is a list of standard elements that may be entered in a field in the database. In the context of these vegetation-mapping projects, LUT relates the elements of one classification to another in a crosswalk. The values of a map classification could be related to the associations of the NVC in a park project.

Map Accuracy. A measure of the maximum error allowed in horizontal location and elevation on maps. For example, the USGS map accuracy standards for 1:24,000-scale maps are that 90% of well-defined objects should appear within 40 ft (12.2 m) of their true location. See United States National Map Accuracy Standards.

Map Attribute. See Attribute.

Map Class. Plant communities and non-vegetated elements that can be discerned on an aerial photograph. If individual plant associations cannot be distinguished on an aerial photograph, map classes lumping related plant associations must be developed. For example, at Devils Tower National Monument there were five associations in the Ponderosa Pine Woodland Alliance, but it was necessary to create two ponderosa pine map classes because the associations could not be distinguished on the photography. Also known as Map Unit.

Map Code. The map class code number related to the map class. For example, map class Canyon Floor Complex has a map code of 10.

Map Scale. The relationship between a distance portrayed on a map and the same distance on the earth's surface (Dana 1999). A scale of 1 in = 1000 ft can also be expressed as 1:12,000 (i.e., 1 in on the map equals 12,000 in on the earth). When a map is reproduced in a different size, the scale reference (1:12,000) is no longer valid but the scale bar on the map is still valid.

Map Projection. A systematic conversion of locations on the Earth's surface from spherical coordinates to planar coordinates (ESRI 1994).

Map Unit. See Map Class.

Map Validation. The process of field checking photointerpretation. This step is completed prior to accuracy assessment.

Metadata. A text file describing how a spatial database was created. Metadata files document how the data were created, their content, quality, condition, and other characteristics. Metadata's purpose is to help organize and maintain an organization's internal investment in spatial data, provide information about an organization's data holdings to data catalogues, clearing-houses, and brokerages, and provide information to process and interpret data received through a transfer from an external source (FGDC

1997). The FGDC sets the content standards for metadata. The NBII has developed software to aid in creating metadata and commercial software programs are also available.

Minimum Mapping Unit (MMU). The smallest area that is consistently delineated during photointerpretation. The MMU for the USGS-NPS Vegetation Mapping Program is 0.5 ha.

Mosaic (Biology). An intermixing of plant associations in an area that has a unique photosignature but is too intricate for individual associations to be delineated. Compare with Complex.

Mosaic (Image). An image composed of an assemblage of edge-matched, overlapping aerial photographs.

National Biological Information Infrastructure (NBII). A broad, collaborative program to provide access to data and information relating to the Nation's biological resources. The NBII links diverse, high-quality biological databases, and analytical tools maintained by NBII partners in government agencies, academic institutions, nongovernmental organizations, and private industries.

National Biological Service (NBS). See Biological Resources Discipline.

National Map Accuracy Standards. See US National Map Accuracy Standards.

National Park Service (NPS). A U.S. Department of Interior agency created in 1916 and charged with preserving the natural and cultural resources of the national park system for the enjoyment, education, and inspiration of this and future generations. NPS manages the National Parks and the Inventory and Monitoring Program and works closely with USGS to coordinate the USGS-NPS Vegetation Mapping Program.

National Vegetation Classification (NVC). A vegetation classification system developed and maintained by NatureServe. It is based on the National Vegetation Classification Standard (NVCS). The NVC can be examined on their on-line NatureServe Explorer database (http://www.natureserve.org/explorer/).

National Vegetation Classification Standard (NVCS). The Federal Geographic Data Committee's vegetation classification model. It has been adapted to the formation level (as of June 2001); adoption of standards for finer levels is expected in the spring of 2004 with the adoption of the Ecological Society of America's 'Guidelines For Describing Associations and Alliances of the U.S. National Vegetation Classification'.

Natural Heritage Programs. Operate throughout much of the western hemisphere gathering, managing, and distributing detailed information about the biological diversity found within their jurisdiction. Most programs are part of government agencies such as fish and wildlife departments, although some are run by universities or non-governmental organizations.

Natural Resources Conservation Service (NRCS). A USDA agency that is the lead federal agency for conservation on private land and is a partner in land conservation with private land managers, conservation districts; resource conservation and development (RC&D) councils; state and local conservation agencies; state, local, and Tribal governments; rural communities; businesses; and others. The NRCS produces the nation's Soil Survey reports.

Natural Vegetation. Plant life of an area that appears to be substantially unaltered by human activities. Most existing vegetation has been subjected to some human modification, so a clear distinction between natural and cultural vegetation may sometimes be difficult (Grossman et al. 1998).

NatureServe. A non-profit organization dedicated to developing and providing knowledge about the world's natural diversity. In cooperation with the Natural Heritage Network, NatureServe collects and develops authoritative information about the plants, animals, and ecological communities of the Western Hemisphere. NatureServe maintains databases to support the National Vegetation Classification (NVC) and the relevé data that it is based on. NatureServe's role in this project was to help develop the vegetation community classification. Formerly known as ABI (Association for Biodiversity Information).

North American Datum (NAD). The standard cartographic reference for map projections and coordinates throughout North America (see also Datum). Usually associated with a version, such as 1927 or 1983. This project used the 1983 North American datum (NAD83), which is consistent with satellite location systems. The 1983 datum uses the GRS 80 spheroid whereas the 1927 datum uses the Clarke 1866 spheroid (ESRI 1994).

Observation Point. Field data used to support map class and vegetation classification development. These points are collected during reconnaissance and verification field work.

Omission Errors. See Producer's Accuracy.

Order. The 2nd highest level in the NVCS hierarchy (FGDC 1997). An order is generally defined by dominant life form (tree, shrub, dwarf shrub, herbaceous, or non-vascular)

Ortho Image. An aerial photograph that has had the distortions common to aerial photography removed and has been registered to locations on the earth. A digital ortho image can be placed in a GIS and have other layers, such as vegetation, overlain on it. A DOQQ is an ortho image. Also sometimes called an ortho-photo.

Pattern. Describes the distribution of vegetation features across a landscape. Some examples include: Evenly Dispersed, Clumped/Bunched, Gradational/Transitional, or Alternating. Compare with Density and Height.

Photointerpretation. The art and science of identifying and delineating objects and conditions on an aerial photograph.

Photointerpretation Key. A description, often accompanied by pictures of examples, of the visual elements that make up the photographic signature of each map class.

Photointerpretation Modifiers. Codes used to describe special features that are not part of the NVCS. For example, an agency may be interested in eagle nests, beaver dams, prairie dog towns, and forest blowdown areas.

Photosignature. See Signature.

Physiognomic Modifiers. Modifiers used to describe the physiognomic structure of the vegetation found within a mapped polygon (e.g., cover, density, pattern, height).

Physiognomy. The structure and life form of a plant community (FGDC 1997).

Plant Association. See Association.

Plant Community. See Community.

PLANTS database. A database maintained by the Natural Resource Conservation Service. This database focuses on vascular plants, mosses, liverworts, hornworts, and lichens of the U.S. and its territories. The PLANTS Database includes names, checklists, automated tools, identification information, species abstracts, distributional data, crop information, plant symbols, plant growth data, plant materials information, links, references, and other information. This is the database that maintains the current list of accepted scientific names. See http://plants.usda.gov/.

Plot. A defined location of a certain size where the data necessary to classify the vegetation is collected. Plots are generally located non-randomly and plot size varies depending on the vegetation being sampled. See: http://biology.usgs.gov/npsveg/fieldmethods. Plot data are entered into a database for storage and analysis. Also referred to as vegetation Relevé.

Polygon. A multisided figure that represents area on a map. A polygon is defined by the lines that consist of the boundary and the label point within its boundary used for identification. Polygons have attributes that describe the geographic feature they represent.

Positional Accuracy. How close a point in a spatial database is to its actual location on the earth's surface. The National Map Accuracy Standard for horizontal positional accuracy at the 1:24,000 scale is 1/50 of an in (40 ft/12.2 m) of an object's actual location.

Potential Vegetation. The vegetation that would become established if succession were completed without interference under the present climatic and edaphic conditions. Contrast with Existing Vegetation.

Precision Lightweight GPS Receiver (PLGR). A small handheld, global positioning system (GPS) receiver developed for the military and featuring anti-spoofing and anti-jamming capability.

Producer's Accuracy. The probability that a reference sample (the ground data) has been classified correctly, also known as error of omission. This quantity is computed by dividing the number of samples that have been classified correctly by the total number of reference samples in that class (Story and Congalton 1986). Compare with User's Accuracy.

Projection. A two-dimensional representation of data located on a curved surface. Projections always involve distortion, so the cartographer must choose which characteristics (distance, direction, scale, area, or shape) will be emphasized at the expense of the other characteristics (Snyder 1982). In this project, all spatial data use the Universal Transverse Mercator (UTM) coordinate system that is based on the transverse mercator projection applied between 84 degrees north and 80 degrees south latitude.

Quadrangle. A USGS 7.5 minute topographic map.

Quarter Quad(rangle). A map or image that includes ¼ of a 7.5-minute quadrangle map. Quarter quadrangles are organized in geographic quadrants of the original map: northeast, northwest, southeast, and southwest.

Rectify. To remove distortions from aerial photographs in the process of transferring interpreted photographs into a spatial database. Distortions on photographs are due to topographic relief on the ground, radial distortion in the geometry of the aerial photography, tip and tilt of the plane, and differences in elevation of the airplane from its nominal scale. This process may be separate or included in the registration process, depending on the technology used.

Reference Data. The field data that is collected for the accuracy assessment.

Register. The process of relating objects on an aerial photograph to the surface of the earth. This is necessary to be able to place vegetation data in a GIS with other spatial data such as roads, topography, or soils. This process may be separate or may be included in the rectification process, depending on the technology used. See also Transfer.

Relevé. See Plot.

Sample Data. Sample data are the map classes that were photo-delineated as occurring on the vegetation map. The sample data is compared to the reference data (see reference data) to compute map accuracy.

Scale. The relationship between a distance portrayed on a map and the same distance on the Earth (Dana 1999). A map scale can be defined by a fraction (e.g., 1 unit on map / 12,000 units on ground) or by a graphic scale bar.

Signature. The unique combination of color, texture, pattern, height, physiognomy, and position in the landscape used by photointerpreters to identify map classes on an aerial photograph. Or, characteristics of an item on a photograph by which the item may be identified (ASP 1984).

Small-scale. Refers to a map or image with a relatively small-scale denominator (e.g. 1:1,000). Small-scale maps cover a small area, have fine detail, and the images have high resolution (e.g. 0.5m per pixel).

Spatial. Refers to features or phenomena distributed in geographic space and having physical, measurable dimensions.

Special Modifiers. See Photointerpretation Modifiers.

Stratum. A horizontal layer of vegetation. A stratum may be defined by the life form of the vegetation (tree, shrub, herbaceous), its relative position in the community (understory) or its actual height.

Structure (Vegetation). The spatial distribution pattern of life forms in a plant community, especially with regard to their height, abundance, or coverage within the individual layers. Synonymous with Physiognomy.

Subclass. The level in the NVCS hierarchies based on growth form characteristics (Grossman et al. 1998).

Subgroup. The level in the NVCS hierarchies that divides each group into either a "natural/semi-natural" or "cultural" (planted/cultivated) subgroup (Grossman et al. 1998).

The Nature Conservancy (TNC). A non-profit conservation organization founded in 1951. Working with communities, businesses and people, TNC protects millions of ac of valuable lands and waters worldwide. TNC was the original caretaker of the National Vegetation Classification, but those responsibilities have been spun off to NatureServe. TNC no longer has an active role with the USGS-NPS Vegetation Mapping Program.

Thematic Accuracy. The correctness of the map classes in relation to the vegetation on the ground. This is determined through standardized accuracy assessment procedures. The program standard is 80% accuracy for each map class within 90% confidence intervals. See Accuracy Assessment, Producer's Accuracy, and User's Accuracy.

Thematic Map. A map that displays the spatial distribution of a single attribute or a specific topic, such as land-cover and land-use classes.

Topology. The explicit definition of how map features represented by points, lines and areas are related. Specifically, accounting for issues of connectivity and adjacency of features.

Topographic Quads. USGS paper maps showing the topography of an area as well as roads, railroads, water bodies, buildings, urban developments, and wetlands. These come in a variety of scales, but commonly refer to 1:24,000-scale 7.5-minute quads. Informally referred to as topo quads.

Transfer. The process of entering data from interpreted aerial photo overlays into a digital database. The data is usually registered and rectified into real-world geographic coordinates. This process varies depending on the type of technology used. See also Transformation.

Transform(ation). The process of converting coordinates (map or image) from one coordinate system to another. This involves scaling, rotation, translation, and warping (images) (ESRI 1994).

Transition Zone. An area where the vegetation composition and structure is intermediate between two associations. The transition zone may be narrow as associations abruptly change due to a significant change in a major habitat factor, such as a cliff, or it may be broad when the physical environment changes gradually. Transition zones may be challenging to classify or map.

Type. A generic term that can mean any vegetation level in the NVCS, whether an association, alliance, formation, etc, or even a combination of levels. It is a vague but useful term. It is correctly used when the focus is not on a specific unit of vegetation, but rather when used loosely to explain some other point (e.g., "We do not have a good grasp of how vegetation types at Acadia link to the map classes."). Also known as Vegetation Type.

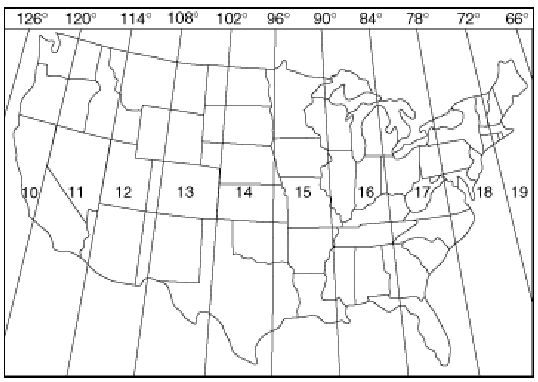
United States Geological Survey (USGS). Established in 1879, the USGS is the natural science agency for the Department of the Interior. The USGS is one of the host agencies, along with the National Park Service, for the USGS-NPS Vegetation Mapping Program.

United States National Map Accuracy Standards. Defines accuracy standards for published maps, including horizontal and vertical accuracy, accuracy testing method, accuracy labeling on published maps, labeling when a map is an enlargement of another map, and basic information for map construction as to latitude and longitude boundaries. The table below shows the standard for some common map scales. Note that the conversion of paper maps into digital data usually creates additional error.

Scale	Engineering Scale	Accuracy Standard
1:1,200	1"=100'	+/- 3.33 ft

1:2,400	1"=200'	+/- 6.67 ft
1:4,800	1"=400'	+/- 13.33 ft
1:9,600	1"=800'	+/- 26.67 ft
1:10,000		+/- 27.78 ft
1:12,000	1"=1000'	+/- 33.33 ft
1:24,000	1"=2000'	+/- 40.00 ft
1:63,360	1"=one mi	+/- 105.60 ft
1:100,000		+/- 166.67 ft

Universal Transverse Mercator (UTM). A map coordinate system (not a map projection) that is defined by the Transverse Mercator projection which has a set of zones defined by a central meridian as shown in the figure below for the United States (ESRI 1994):



User's Accuracy. In assessing the thematic accuracy of a vegetation map, the probability that a sample from the mapped data actually represents that category on the ground, also known as error of commission. This quantity is computed by dividing the number of correctly classified samples by the total number of samples that were classified as belonging to that category (Story and Congalton 1986). Compare with Producer's Accuracy.

Vector Data. Spatial (usually digital) data that consists of using coordinate pairs (x, y) to represent locations on the earth. Features can take the form of single points, lines, arcs or closed lines (polygons).

Vegetation. The plant cover over an area (FGDC 1997).

Vegetation Characterization. The detailed description of a plant association's diagnostic and dominant species, structure, and/or ecological processes. See: http://biology.usgs.gov/npsveg/agfo/descript.pdf

Vegetation Classification. The process of categorizing vegetation into recognizable and consistent elements. Also a document that lists and organizes the vegetation communities in an area. An example of a vegetation classification can be found at http://biology.usgs.gov/npsveg/agfo/methods.pdf classification.

Vegetation Community.
See Community.

Vegetation Description.
See Vegetation Characterization.

Vegetation (Field) Key.
See Dichotomous Field Key.

Vegetation Mapping. The process of identifying, labeling, and locating vegetation communities using real world coordinates.

Vegetation Structure. See Structure.

Vegetation Type. See Type.

Vertical Aerial Photography.
See Aerial Photography.

Wetland. A community or landscape type that is characterized by either hydric soils or hydrophytic plants or both. A wetland may be vegetated or non-vegetated.

Gl

Glossary Literature Cited

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APPENDIX A

A. CD-ROM Readme Text and CD-ROM

(Included as Readme.doc file on the CD-ROM)

The following is the text of the Readme.doc document for the CD-Rom that accompanies this report. This CD-Rom contains all coverages and GIS data developed for the WACA vegetation map, databases for vegetation classification relevés and accuracy assessment observations, field photos, report files, and associated metadata. The associated metadata describes the attributes in all of the coverages and databases. We also include a list of appropriate citations below each of the coverages or databases to be used when citing these sources.

The files are arranged on the CD-Rom as follows:

readme.doc – This file

1. Ancillary_Data - This folder contains 4 subfolders with information on the park, project, and imagery boundary files. Each subfolder contains a coverage in Arc/Info export format (.e00), a shape file, a coverage, and associated metadata:

    a. <u>Flightline_bndry</u>- Flightline boundaries used to develop the aerial photography
    Citation:
    U.S. Bureau of Reclamation Remote Sensing and GIS Group. 2004. Flight Line Coverage: Walnut Canyon National Monument. A digital spatial database (ArcInfo). U.S. Geological Survey.

    b. <u>Park_bndry</u>- Boundary of Walnut Canyon National Monument
    Citation:
    Flagstaff Area National Monuments. 2004. Boundary: Walnut Canyon National Monument, AZ. A digital spatial database (ArcInfo). U.S. Geological Survey.

    c. <u>Proj_bndry</u>- Boundary for vegetation map for Walnut Canyon National Monument
    Citation:
    U.S. Bureau of Reclamation Remote Sensing and GIS Group. 2004. Project Boundary: Walnut Canyon National Monument Vegetation Mapping Project. A digital spatial database (ArcInfo). U.S. Geological Survey.

    d. <u>Quad_Doqq_bndry</u>- Boundary of the USGS topographic quadrant maps and the digital orthophoto quarter quads boundaries used for the development of the vegetation map for Walnut Canyon National Monument
    Citation:
    U.S. Bureau of Reclamation Remote Sensing and GIS Group. 2004. Boundary: Flagstaff Area National Monuments USGS Quadrangle and DOQQs. A digital spatial database (ArcInfo). U.S. Geological Survey.

2. Basemap folder – This folder contains the MrSid compressed mosaic of the DOQQs and associated metadata for Walnut Canyon National Monument. The MrSid images can be viewed as images in ArcView using the MrSid extension.

Citation:
U.S. Geological Survey. 2004. DOQQ Basemap: Walnut Canyon National Monument. Digital orthophotoquads. U.S. Geological Survey.

3. Ground Photos (.tif/.jpeg) - This folder contains photos for each relevé collected for the vegetation classification. Each photo is listed as "WC-***a/b/c" where the WC stands for Walnut Canyon, the *** indicates the relevé number, and either a, b, or c is listed after the prefix corresponding sequentially to the number of photos taken at each relevé point. For example, at relevé number WC-032 two photos were taken and are listed as WC-032a and WC-032b. For additional information on the aspect and time of the photo taken at each relevé refer to the Vegetation Relevé Database described below.

4. Map_Demo – This folder contains an ArcView project file (.apr), associated data that was used to create the final vegetation map, and a readme.txt file. To open the project, a copy of this folder must be placed on your hard drive. You will also need the ArcPress extension. Start ArcView and then navigate to the project file (WACA_veg.apr). Further information can be found in the included readme.txt file.

5. Project_Report - The folder contains the entire report (WACA_Final_Report.pdf) in an Adobe Acrobat .pdf format.

6. Vegetation_Data – This folder contains all the spatial data (final vegetation GIS cover including a vegetation map clipped to the park boundary, observation point cover, seeps and springs cover, accuracy assessment points cover and classification relevé cover) and databases (Vegetation Relevé Database) used to create the final vegetation map as well as associated metadata.
   a. Accuracy Assessment
      1. Database-Microsoft access database named WACA_AAdatabase.mdb with all the information collected in the field during the accuracy assessment observations
         Citation:
         Hansen, M. and K. Thomas. 2004. Walnut Canyon National Monument: Accuracy Assessment Database. A MS Access database. U.S. Geological Survey.
      2. Metadata-All associated metadata for the spatial data and the accuracy assessment database
      3. Spatial data- A coverage and shapefile of the accuracy assessment points used in the accuracy assessment analysis
      4. waca_aa_pts.e00-An Arc/Info export format (.e00) of the accuracy assessment points
         Citation:
         Dale, B., M. Hansen, and K. Thomas. 2004. Accuracy Assessment Points: Walnut Canyon National Monument. A digital spatial database (ArcInfo). U.S. Geological Survey.

b. Clip_Veg

1. Metadata- Associated metadata for the spatial data
2. Spatial data- A coverage and shapefile of the vegetation map clipped to the Walnut Canyon National Monument boundary
3. waca_clip_veg.e00-An Arc/Info export format (.e00) of the cover of vegetation map clipped to the Walnut Canyon National Monument boundary

   Citation:

   U.S. Bureau of Reclamation Remote Sensing and GIS Group. 2004. Clipped Vegetation Coverage: Walnut Canyon National Monument Vegetation Mapping Project. A digital spatial database (ArcInfo). U.S. Geological Survey.

c. Observation_Points

1. Metadata- Associated metadata for the spatial data
2. Spatial data- A point coverage and shapefile of the observation points used to help with the photointerpretative work
3. waca_obs.e00-An Arc/Info export format (.e00 files) of the observation points collected in the field to help with the photointerpretative work

   Citation:

   U.S. Bureau of Reclamation Remote Sensing and GIS Group. 2004. Observation Point Coverage: Walnut Canyon National Monument Vegetation Mapping Project. A digital spatial database (ArcInfo). U.S. Geological Survey.

d. Releve_Plots

1. Database- Microsoft access database named WACA_FieldReleve_database.mdb with all the information collected in the field at each field relevé

   Citation:

   Hansen, M. and K. Thomas. 2004. Walnut Canyon National Monument: Field Relevé Plots. A MS Access database. U.S. Geological Survey.
2. Metadata- Associated metadata for the database and spatial data
3. Spatial data- A coverage and shapefile of the field relevés
4. waca_releve.e00-An Arc/Info export format (.e00) of the cover of field relevé points sampled in the Walnut Canyon project boundary

   Citation:

   Hansen, M. and K. Thomas. 2004. Field Relevé Plots: Walnut Canyon National Monument Vegetation Mapping Project. A digital spatial database (ArcInfo). U.S. Geological Survey.

e. Seeps_Springs_Wetlands

1. Metadata-Associated metadata for the spatial data
2. Spatial data- A coverage and shapefile of the occurrence of seeps, springs, and wetlands in the Walnut Canyon Vegetation Mapping Project

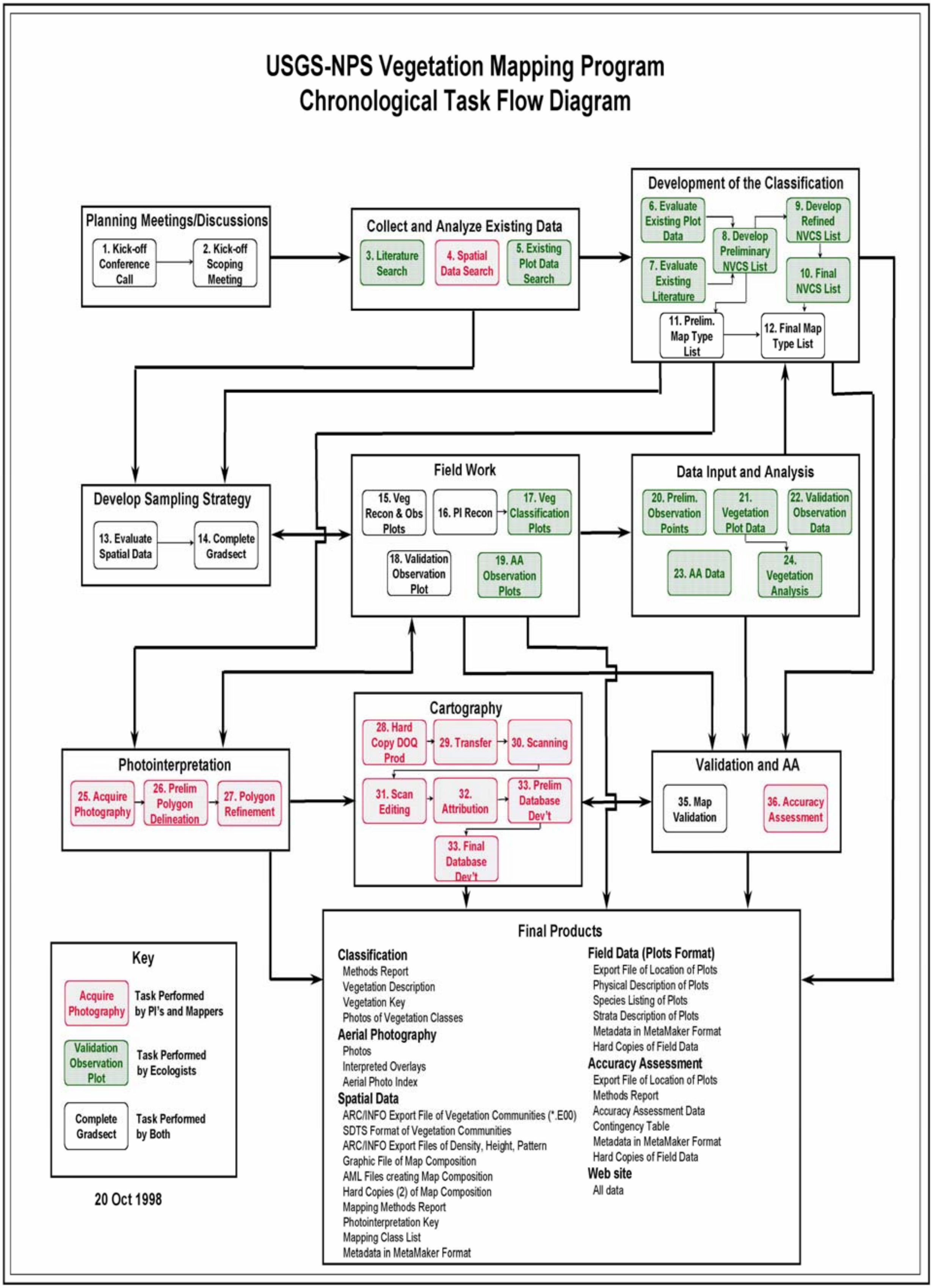
3. waca_seeps.e00-An Arc/Info export format (.e00) of the cover of seeps, springs, and wetlands in the project boundary
   Citation:
   U.S. Bureau of Reclamation Remote Sensing and GIS Group. 2004. Seeps, Springs, and Wetlands Coverage: Walnut Canyon National Monument. A digital spatial database (ArcInfo). U.S. Geological Survey.

f. Vegetation_Map
   1. Metadata- Associated metadata for the spatial data
   2. Spatial data- A coverage and shapefile of the vegetation map for Walnut Canyon National Monument and the project environs
   3. waca_veg.e00-An Arc/Info export format (.e00) of the cover of the vegetation map coverage
      Citation:
      U.S. Bureau of Reclamation Remote Sensing and GIS Group. 2004. Walnut Canyon National Monument Vegetation Map. A digital spatial database (ArcInfo). U.S. Geological Survey.

APPENDIX B

B. Flowchart of USGS-NPS National Parks Vegetation Mapping Program

(Created by Tom Owens, USGS)


USGS-NPS Vegetation Mapping Program
Chronological Task Flow Diagram
Planning Meetings/Discussions
1. Kick-off Conference Call
2. Kick-off Scoping Meeting
Collect and Analyze Existing Data
3. Literature Search
4. Spatial Data Search
5. Existing Plot Data Search
Development of the Classification
6. Evaluate Existing Plot Data
7. Evaluate Existing Literature
8. Develop Preliminary NVCS List
9. Develop Refined NVCS List
10. Final NVCS List
11. Prelim. Map Type List
12. Final Map Type List
Develop Sampling Strategy
13. Evaluate Spatial Data
14. Complete Gradsect
Field Work
15. Veg Recon & Obs Plots
16. PI Recon
17. Veg Classification Plots
18. Validation Observation Plot
19. AA Observation Plots
Data Input and Analysis
20. Prelim. Observation Points
21. Vegetation Plot Data
22. Validation Observation Data
23. AA Data
24. Vegetation Analysis
Cartography
28. Hard Copy DOQ Prod
29. Transfer
30. Scanning
31. Scan Editing
32. Attribution
33. Prelim Database Dev't
33. Final Database Dev't
Photointerpretation
25. Acquire Photography
26. Prelim Polygon Delineation
27. Polygon Refinement
Validation and AA
35. Map Validation
36. Accuracy Assessment
Final Products
Classification
Methods Report
Vegetation Description
Vegetation Key
Photos of Vegetation Classes
Aerial Photography
Photos
Interpreted Overlays
Aerial Photo Index
Spatial Data
ARC/INFO Export File of Vegetation Communities (*.E00)
SDTS Format of Vegetation Communities
ARC/INFO Export Files of Density, Height, Pattern
Graphic File of Map Composition
AML Files creating Map Composition
Hard Copies (2) of Map Composition
Mapping Methods Report
Photointerpretation Key
Mapping Class List
Metadata in MetaMaker Format
Field Data (Plots Format)
Export File of Location of Plots
Physical Description of Plots
Species Listing of Plots
Strata Description of Plots
Metadata in MetaMaker Format
Hard Copies of Field Data
Accuracy Assessment
Export File of Location of Plots
Methods Report
Accuracy Assessment Data
Contingency Table
Metadata in MetaMaker Format
Hard Copies of Field Data
Web site
All data
Key
Acquire Photography
Task Performed by PI's and Mappers
Validation Observation Plot
Task Performed by Ecologists
Complete Gradsect
Task Performed by Both
20 Oct 1998

APPENDIX C

C. Photointerpretation Observations, Classification Relevés, and Accuracy Assessment Observations Forms

NATIONAL PARK VEGETATION MAPPING PROGRAM:
PHOTOINTERPRETATION OBSERVATION FORM

IDENTIFIERS/LOCATORS

Plot Code____ Polygon Code_________________________________

Provisional Community Name____

State ___ Park Name ____ Park Site Name ___________________________

Quad Name____ Quad Code______________________________

GPS file name________________Field UTM X___ ___ ___ ___ ___ ___ m E Field UTM Y___ ___ ___ ___ ___ ___ ___ m N

please do not complete the following information when in the field
Corrected UTM X___ ___ ___ ___ ___ ___ m E Corrected UTM Y___ ___ ___ ___ ___ ___ ___ m N UTM Zone___________

Survey Date_____________ Surveyors____

ENVIRONMENTAL DESCRIPTION

Elevation _______________________ Slope ______________________ Aspect__________________________

Topographic Position

Landform

Cowardian System	Hydrologic Regime		Salinity/Halinity Modifiers
___Upland ___Riverine ___Palustrine ___Lacustrine	Non-Tidal ___Permanently Flooded ___Semipermanently Flooded ___Seasonally Flooded	___Saturated ___Temporarily Flooded/Saturated ___Intermittently Flooded	___Saltwater ___Brackish ___Freshwater

Environmental Comments:	Unvegetated Surface: *(please use the cover scale below)*
	___ Bedrock ___ Litter, duff ___ Wood (> 1 cm) ___ Large rocks (cobbles, boulders > 10 cm) ___ Small rocks (gravel, 0.2-10 cm) ___ Sand (0.1-2 mm) ___ Bare soil ___ Other:____

VEGETATION DESCRIPTION

Leaf phenology (of dominant stratum)	Leaf Type (of dominant stratum)	Physiognomic class	Cover Scale for Strata & Unvegetated Surface	Height Scale for Strata
Trees and Shrubs ___Evergreen ___Cold-deciduous ___Drought-deciduous ___Mixed evergreen - cold-deciduous ___Mixed evergreen - drought-deciduous Herbs ___Annual ___Perennial	___Broad-leaved ___Needle-leaved ___Mixed broad-leaved/Needle leaved ___Microphyllous ___Graminoid ___Forb ___Pteridophyte	___Forest ___Woodland ___Shrubland ___Dwarf Shrubland ___Herbaceous ___Nonvascular ___Sparsely Vegetated	01 5% 02 10% 03 20% 04 30% 05 40% 06 50% 07 60% 08 70% 09 80% 10 90% 11 100%	01 <0.5 m 02 0.5-1m 03 1-2 m 04 2-5 m 05 5-10 m 06 10-15 m 07 15-20 m 08 20-35 m 09 35 - 50 m 10 >50 m

Strata	Height	Cover Class	Dominant species (mark any known diagnostic species with a *)	Cover Class
T1 Emergent	_____	_____		
T2 Canopy	_____	_____		
T3 Sub-canopy	_____	_____		
S1 Tall shrub	_____	_____		
S2 Short Shrub	_____	_____		
S3 Dwarf-shrub	_____	_____		
H Herbaceous	_____	_____		
N Non-vascular	_____	_____		
V Vine/liana	_____	_____		
E Epiphyte	_____	_____		

please see the table on the previous page for height and cover scales for strata

Other Comments

Cover Scale for Species

01	<1%
02	1-5%
03	5-25%
04	25-50%
05	50-75%
06	75-100%

CLASSIFICATION RELEVÉ FORM

SURVEY AND SITE INFORMATION

Park Name:______________________ Date:_________________________
Surveyors____

Plot Code____________________________________
Provisional Alliance/Association Name____

Zone 12 **Datum NAD 83**
USGS Quad__________________________________ 7.5 or 15' Environ-Code_________

Air Photo #______________________ Polygon Code__________________________
UTM E___________________m UTM N______________m Way Point__________

Error =+/-__________
Landowner(check one):NPS___ Forest Service ___ Private(owner if known) _________ State Lands: Game and Fish ___.

Plot length__________ m Plot width______________ m Plot Shape: (square, rectangle, triangle, circle)
Circle Diameter=35.6m for 1000m^2, Diameter=22.6 for 400m^2

Directions to Plot____
____
____

Plot Photos (Y/N)__________ Roll #______ Frame #_________________ Direction__________
Date_________ Time______________

ENVIRONMENTAL DESCRIPTION

Elevation___________ (m.) Slope________ % Aspect______________

Topographic position:________Landform:__________(enter number from Code Sheet)

Community Type:__________(Wetland(W) or Upland(U))
(if W then)

__Estuarine	__Semipermanently Flooded	__Permanently Flooded	Salinity/Halinity
__Riverine	__Seasonally Flooded	__Permanently Flooded-tidal	Modifiers:
__Palustrine	__Saturated	__Tidally Flooded	__Saltwater
__Laustrine	__Temporarily Flooded	__Artificially Flooded	__Brackish
	__Intermittently Flooded		__Freshwater

VEGETATION DESCRIPTION

Vegetation Group:_________(from the three columns below)

Leaf phenology:	**Leaf Type:**	**Physiognomic class:**
Trees and Shrubs	1__Broad-leaved	1__Forest
1__Evergreen	2__Needle-leaved	2__Woodland
2__Cold-deciduous	3__Microphyllous	3__Shrubland
3__Drought-deciduous	4__Graminoid	4__Dwarf shrubland
4__Mixed evergreen-cold-deciduous	5__Broad-leaved herbaceous	5__Herbaceous (grassland and forb)
5__Mixed evergreen drought-deciduous	6__Pteridophyte	6__Nonvascular
Herbs	7__Mixed broad and needle-leaved	7__Sparsely vegetated
6__Annual	8__Extremely xeromorphic	
7__Perennial	9__Hydromorphic	

Additional Comments:

Plot #_______________ Date:_______________

Cover Class Intervals: 1(<1%), 2(1-5%), 3(>5-10%), 4(>10-25%), 5(>25-50%), 6(50-75%), 7(>75%)
G=Ground(<0.5m), S-Shrub(0.5-3.0m), T-Tree(>3.0m)
Layer

G	S	T	Vascular plant name	Final determination	Cover Class	%

(Fill data only once per field plot!)
Total Vegetation Cover(Class): ______Total Tree______ Total Shrub______ Total Ground_____ Total Non-native______
%______ ______ _____ __

Cover Scale for Strata, Sensitive Species, Exotics, Biotic Surfaces and Unvegetated Surface:

01	<1%	03	>5-10%	05	>25-50%	07	>75%
02	>1-5%	04	>10-25%	06	>50-75		

Unvegetated Surface	Bare Soil	Sand (0.1-2mm)	Gravel (2mm-6.4cm)	Cobble (6.4-19cm)	Stone (>19-61cm)	Boulder (>61 cm)	Bedrock	Litter, duff	Biotic Crust (cryptogram moss, lichen
Cover Class									

Environmental Comments:	Soil Taxon/Description:

Strata	Moss/Lichen	0-25cm	25-50cm	0.5-1m	1-3m	3-5m	5-10m	10-20m	20-30m	>30m
Cover Class										

Sensitive Species:

Genus	Species	% Cover	Cover Class

Exotic Species:

Genus	Species	% Cover	Cover Class

DBH Table:

Species	Diameter	Species	Diameter

3-Flagstaff Park's Code Sheet for Classification Relevés

MACRO TOPOGRAPH

00 INTERFLUVE(crest, summit, ridge): linear top of ridge, hill, or mountain; elevated area between two fluves
01 HIGH SLOPE(shoulder slope, upper slope, convex creep slope): the top of a slope, convex
02 HIGH LEVEL(mesa): top of plateau
03 MIDSLOPE(transportational midslope, middle slope): intermediate slope
04 BACKSLOPE(dipslope): subset of midslopes which are steep, linear, and cliff segments
05 STEP IN SLOPE(ledge, terracetee): nearly level shelf interrupting a steep slope, rock wall, or cliff face
06 LOWSLOPE(lower slope, foot slope, colluvial footslope): inner gently inclined surface at the base of a slope, concave
07 TOESLOPE(alluvial toeslope): outermost gently inclined surface at base of slope, commonly gentle and linear
08 LOW LEVEL(terrace): valley floor or shoreline representing the former position of an alluvial plain, lake or shore
09 CHANNEL WALL(bank): sloping side of a channel
10 CHANNEL BED(narrow valley bottom, gully arroyo): bed of single or braided watercourse commonly barren of vegetation
11 BASIN FLOOR(depression): nearly level to gently sloping, bottom surface of a basin

LANDFORM

20 **Rockpile**=uplands composed primarily of jointed and efoliating granitic outcrops
21 **Bajada**=alluvial slopes of fans that accumulate at the base of a desert mountain or mountain canyons that are interrupted by the trenching of minor water sources
22 **Drainage Channel**=bottom not side slope of a drainage confined by banks or a canyon
23 **Valley Bottom Fill**=usually level places
24 **Playa**=Pleistocene dried lakebed often with some surface water
25 **Side Slope**=side of drainage channels
26 **Lower Slope**=lower better watered portion of a slope
27 **Mid Slope**=central portion of a slope
28 **Upper Slope**=the upper driest portion of a slope
29 **Interfluve**=the area between small drainage channels
30 **Ridge**=high ground between two opposing slopes
31 **Slick Rock**=large exposed expanses of bedrock
32 **Terrac**e=level or gently sloping shelf perched on a slope, often caused by down-cutting rivers
33 **Mesa**=level or gently sloping ground surrounded on 3 or more sides by steep down slopes and capped
34 **Butte**=similar to a mesa, except with a top that does not have a flat configuration
35 **Cliff**=very steep rock slopes
36 **Talus**=unsorted material resulting from mass wasting of steep mountain slopes
37 **Sand Dune/Sand Sheet**=large accumulations of sand, may be stable or unstable (moving)

ACCURACY ASSESSMENT OBSERVATION FORM

SURVEY AND SITE INFORMATION

Park Name:__Walnut Canyon________________ Date:_______________________
Surveyors___________________________
Plot Code_________________________________

Zone 12 **Datum NAD 83**
USGS Quad_______________________________ 7.5
UTM E_______________________m UTM N___________________m Way Point_________
Error =+/-_________
Elevation ________________(m)

PLEASE CIRCLE CLOSEST MAP CLASS REPRESENTING SITE:

Vegetation:
Blue Grama - Mt. Muhly Grassland Group
Canyon Floor Complex
Common Horehound - Prairie Dog Town
Douglas-fir / Gambel Oak Forest
Introduced Western Wheatgrass Grassland
Limestone Rim Complex
Pinyon Pine - Utah Juniper / Blue Grama Woodland
Ponderosa Pine - Pinyon Pine - Juniper - / Gambel Oak Woodland
Ponderosa Pine - Pinyon Pine - Juniper / Blue Grama Woodland
Ponderosa Pine / Gambel Oak Woodland
Ponderosa Pine / Mixed Graminoid Woodland Complex
Rabbitbrush / Blue Grama Shrub Herbaceous Vegetation
Snakeweed / Modified Grassland Complex

Geomorphology:
Sparsely Vegetated Coconino Sandstone
Sparsely Vegetated Intermittent Drainage Channel
Sparsely Vegetated Kaibab Limestone

Land Use:
NPS Facilities
Pastures
Ranch Developments
Rural Residential
Stock Tanks and Dams
Transportation Routes
Utility Corridors

CONFIDENCE: Exact Good (Some problems) Poor None that fit

Please explain all reasons for Good, Poor or None Confidence

PLEASE CIRCLE CLOSEST ASSOCIATION/ALLIANCE REPRESENTING SITE:

Acer negundo / Forestiera pubescens – Symphoricarpos rotundifolius Temporarily Flooded Shrubland *Aristida purpurea* Herbaceous Vegetation *Bouteloua eriopoda* Herbaceous Vegetation *Bouteloua gracilis He*rbaceous Vegetation *Bouteloua gracilis* Herbaceous Vegetation *Bromus* (*tectorum, rubens*) Semi-natural Herbaceous Alliance *Chamaebatiaria millefolium - (Mahonia fremontii)* – *Yucca baccata* Limestone Terrace Shrubland *Chamaebatiaria millefolium - Forestiera pubescens* Shrubland *Ericameria nauseosa - Gutierrezia sarothrae* Shrubland *Ericameria nauseosa / Bouteloua gracilis* Shrub Herbaceous Vegetation *Gutierrezia sarothrae* Modified Dwarf-shrubland [provisional] *Juniperus osteosperma* Woodland Alliance *Juniperus scopulorum* Woodland Alliance	*Muhlenbergia montana* Herbaceous Vegetation *Pascopyrum smithii* Herbaceous Vegetation *Pinus edulis –(Juniperus osteosperma) / (Bouteloua gracilis)* Woodland *Pinus edulis / Cercocarpus montanus* Woodland *Pinus edulis / Purshia stansburiana* Woodland *Pinus ponderosa – (Pinus edulis – Juniperus osteosperma) / Bouteloua gracilis* Woodland *Pinus ponderosa – (Pinus edulis – Juniperus osteosperma) / Quercus gambelii* Woodland *Pinus ponderosa / Quercus gambelii* Woodland *Pinus ponderosa / Bouteloua gracilis* Woodland *Pinus ponderosa / Muhlenbergia montana* Woodland *Pseudotsuga menziesii / Quercus gambelii* Woodland *Quercus gambelii / Robinia neomexicana / Symphoricarpos rotundifolius* Shrubland

CONFIDENCE: Exact Good (Some problems) Poor None that fit

Please explain all reasons for Good, Poor or None Confidence

APPENDIX F

F. Walnut Canyon National Monument Species List

(Species list was compiled from the relevé data collected in 1999
as part of the USGS-NPS National Mapping Program)

Family	Scientific Name	Common Name
Aceraceae	*Acer negundo* L.	boxelder
Agavaceae	*Agave parryi* Engelm.	Parry's agave
	Yucca angustissima Engelm. ex Trel.	narrowleaf yucca
	Yucca baccata Torr.	banana yucca
Amaranthaceae	*Amaranthus biltoides* S. Wats.	mat amaranth
Anacardiaceae	*Rhus trilobata* Nutt.	skunkbush sumac
	Toxicodendron radicans (L.) Kuntze	eastern poison ivy
Apiaceae	*Pseudocymopterus montanus* (Gray) Coult. & Rose	alpine false springparsley
Apocynaceae	*Apocynum cannabinum* L.	Indianhemp
Asclepiadaceae	*Asclepias asperula* (Dcne.) Woods.	spider milkweed
	Asclepias subverticillata (Gray) Vail	horsetail milkweed
	Asclepias sp. L.[1]	milkweed
Asteraceae	*Achillea millefolium* L.	common yarrow
	Ambrosia acanthicarpa Hooke.	flatspine burr ragweed
	Ambrosia artemisiifolia L.	annual ragweed
	Ambrosia tomentosa Nutt.	skeletonleaf burr ragweed
	Antennaria marginata Greene	whitemargin pussytoes
	Antennaria parviflolia Nutt.	small-leaf pussytoes
	Artemisia campestris ssp. *pacifica* (Nutt.) Hall & Clements	field sagewort
	Artemisia carruthii Wood ex Carruth.	Carruth's sagewort
	Artemisia dracunculus ssp. *dracunculus* L.	tarragon
	Artemisia frigida Willd.	prairie sagewort
	Artemisia ludoviciana Nutt.	white sagebrush
	Aster sp. L.	aster
	Bahia dissecta (Gray) Britt.	ragleaf bahia
	Brickellia californica (Torr. & Gray) Gray	California brickellbush
	Brickellia grandiflora (Hook.) Nutt.	tasselflower brickellbush
	Brickellia sp. Ell.	brickellbush
	Chaetopappa ericoides (Torr.) Nesom	rose heath
	Chrysothamnus depressus Nutt.	longflower rabbitbrush
	Chrysothamnus sp. Nutt.	rabbitbrush
	Cirsium arizonicum (Gray) Petrak	Arizona thistle
	Cirsium calcareum (M.E. Jones) Woot. & Standl.	Cainville thistle
	Cirsium wheeleri (Gray.) Petrak	Wheeler's thistle
	Cirsium sp. P. Mill.	thistle
	Ericameria nauseosus ssp. *nauseosa* var. *nauseosa* (Pallas ex Pursh) Nesom & Baird	rubber rabbitbrush
	Erigeron divergens Torr. & Gray	spreading fleabane
	Erigeron flagellaris Gray	trailing fleabane
	Erigeron formosissimus Greene	beautiful fleabane
	Gaillardia pinnatifida Torr.	red dome blanketflower
	Grindelia nuda Wood var. *aphanactis* (Rydb.) Nesom	curlytop gumweed
	Gutierrezia sarothrae (Pursh) Britt. & Rusby	broom snakeweed

[1] Genera that do not include specific epithets are unique unidentified species.

Family	Scientific Name	Common Name
	Helianthus petiolaris Nutt.	prairie sunflower
	Heliomeris longifolia var. *annua* (M.E. Jones) Yates	longleaf false goldeneye
	Heliomeris multiflora var. *multiflora* Nutt.	showy goldeneye
	Heterotheca villosa (Pursh) Shinners	hairy false goldenaster
	Hymenopappus filifolius var. *lugens* (Greene) Jepson	Idaho hymenopappus
	Hymenoxys bigelovii (Gray) Parker	Bigelow's rubberweed
	Hymenoxys richardsonii (Hook.) Cockerell	pingue rubberweed
	Lactuca serriola L.	prickly lettuce
	Machaeranthera canescens ssp. *canescens* var. *canescens* (Pursh) Gray	hoary tansyaster
	Machaeranthera gracilis (Nutt.) Shinners	slender goldenweed
	Machaeranthera grindelioides var. *grindelioides* (Nutt.) Shinners	rayless tansyaster
	Packera multilobata (Torr. & Gray ex Gray) W.A. Weber & A. Löve	lobeleaf groundsel
	Packera neomexicana var. *neomexicana* (Gray) W.A. Weber & A. Löve	New Mexico groundsel
	Parthenium incanum Kunth.	mariola
	Psilostrophe sparsiflora (Gray) A. Nels.	greenstem paperflower
	Senecio flaccidus var. *flaccidus* Less.	threadleaf ragwort
	Senecio spartioides Torr. & Gray	broomlike ragwort
	Senecio sp. L.	ragwort
	Solidago canadensis L.	Canada goldenrod
	Solidago velutina DC.	threenerve goldenrod
	Stephanomeria sp. Nutt.	wirelettuce
	Symphyotrichum falcatum var. *crassulum* (Rydb.) Nesom	white prarie aster
	Tetradymia canescens DC.	spineless horsebrush
	Tetraneuris acaulis var. *acaulis* (Pursh) Greene	stemless four-nerve daisy
	Tragopogon dubius Scop.	yellow salsify
Berberidaceae	*Mahonia fremontii* (Torr.) Fedde	Fremont's mahonia
	Mahonia haematocarpa (Woot.) Fedde	red barberry
	Mahonia repens (Lindl.) G. Don	creeping barberry
Boraginaceae	*Cryptantha cinerea* var. *jamesii* Cronq.	James' cryptantha
	Lappula occidentalis (S. Wats.) Greene	flatspine stickseed
	Lithospermum multiflorum Torr. ex Gray	manyflowered stoneseed
	Macromeria viridiflora DC.	giant-trumpets
Brassicaceae	*Descurainia incana* ssp.*incana* (Bernh. ex Fisch. & C.A. Mey.) Dorn	mountain tansymustard
	Descurainia obtusa (Greene) O.E. Schulz	blunt tansymustard
	Descurainia sophia (L.) Webb ex Prantl	herb sophia
	Draba asprella Greene	rough draba
	Lesquerella intermedia (S. Wats.) Heller	mid bladderpod
Cactaceae	*Echinocereus* sp. Engelm.	hedgehog cactus
	Echinocereus triglocidiatus Engelm.	kingcup cactus
	Mammillaria sp. Haw	globe cactus
	Opuntia phaeacantha Engelm.	tulip pricklypear
	Opuntia sp. P. Mill.	pricklypear
Cannabaceae	*Humulus lupulus* var. *lupuloides* E. Small	common hop
Caprifoliaceae	*Lonicera arizonica* Rehd.	Arizona honeysuckle

Family	Scientific Name	Common Name
	Sambucus nigra ssp. Cerulea (Raf.) R. Bolli	European black elderberry
	Symphoricarpos rotundifolius var. *parishii* (Rydb.) Dempster	Parish's snowberry
	Symphoricarpus oreophilus Gray	mountain snowberry
Caryophyllaceae	*Arenaria eastwoodiae* Rydb.	Eastwood's sandwort
	Arenaria lanuginosa (Michx.) Rohrb.	spreading sandwort
Chenopodiaceae	*Atriplex canescens* (Pursh) Nutt.	fourwing saltbush
	Chenopodium berlandieri Moq.	pitseed goosefoot
	Chenopodium fremontii S. Wats.	Fremont's goosefoot
	Chenopodium graveolens Willd.	fetid goosefoot
	Krascheninnikovia lanata (Pursh) Guldenstaedt	winterfat
	Salsola tragus L.	prickly Russian thistle
Convolvulaceae	*Convolvulus arvensis* L.	field bindweed
Cornaceae	*Cornus sericea* ssp. *sericea* L.	redosier dogwood
Crassulaceae	*Sedum cockerellii* Britt.	Cockerell's stonecrop
Cupressaceae	*Juniperus deppeana* Steud.	alligator juniper
	Juniperus monosperma (Engelm.) Sarg.	oneseed juniper
	Juniperus osteosperma (Torr.) Little	Utah juniper
	Juniperus scopulorum Sarg.	Rocky Mountain juniper
	Juniperus sp. L.	juniper
Cyperaceae	*Carex foenea* var. *foenea* Willd.	dryspike sedge
	Carex sp.	sedge
Ephederaceae	*Ephedra viridis* Coville	mormon tea
Euphorbiaceae	*Chamaesyce fendleri* (Torr. & Gray) Small	Fendler's sandmat
	Euphorbia brachycera Engelm.	horned spurge
	Euphorbia sp. L.	spurge
Fabaceae	*Astragalus humistratus* Gray	groundcover milkvetch
	Astragalus lentiginosus Dougl. ex Hook.	freckled milkvetch
	Astragalus sp. L.	milkvetch
	Lotus wrightii (Gray) Greene	Wright's deervetch
	Lupinus argenteus Pursh	silvery lupine
	Lupinus sp. L.	lupine
	Medicago sativa L.	alfalfa
	Melilotus officinalis (L.) Lam.	yellow sweetclover
	Mimosa sp. L.	sensitive plant
	Oxytropis lambertii Pursh	purple locoweed
	Phaseolus angustissimus Gray	slimleaf bean
	Psoralidium tenuiflorum (Pursh) Rydb.	slimflower scurfpea
	Robinia neomexicana Gray	New Mexico locust
	Vicia americana Muhl. Ex Willd.	American vetch
Fagaceae	*Quercus gambelii* Nutt.	Gambel oak
Geraniaceae	*Erodium cicutarium* (L.) L'Her. ex Ait	redstem stork's bill
	Geranium caespitosum James	pineywoods geranium
	Geranium caespitosum var. *eremophilum* (Woot. & Standl.) W.C Martin & C.R. Hutchins	purple cluster geranium
	Geranium sp. L.	geranium
Grossulariaceae	*Ribes cereum* Dougl.	wax currant

Family	Scientific Name	Common Name
Hydrophyllaceae	*Phacelia egena* (Greene ex Brand) Greene ex J.T. Howell	Kaweah River phacelia
Iridaceae	*Iris missouriensis* Nutt.	Rocky Mountain iris
Juglandaceae	*Juglans major* (Torr.) Heller	Arizona walnut
Lamiaceae	*Hedeoma hyssopifolia* Gray	aromatic false pennyroyal
	Hedeoma nana ssp. *macrocalyx* W.S. Stewart	dwarf false pennyroyal
	Hedeoma sp. Pers.	false pennyroyal
	Marrubium vulgare L.	horehound
	Monarda fistulosa ssp. *fistulosa* var. *menthifolia* (Graham) Fern.	wild bergamot
	Monardella odoratissima Benth.	mountain monardella
Liliaceae	*Disporum trachycarpum* (S. Wats.)Benth. & Hook. f.	roughfruit fairybells
	Maianthemum racemosum (L.) Link	feathery false lily of the vally
	Maianthemum stellatum (L.) Link	starry false lily of the vally
	Zigadenus elegans Pursh	mountain deathcamas
Linaceae	*Linum lewisii* Pursh	prairie flax
	Linum neomexicanum Greene.	New Mexico yellow flax
	Linum sp. L.	flax
Malvaceae	*Malva neglecta* Wallr.	common mallow
	Sphaeralcea fendleri Gray	Fendler's globemallow
	Sphaeralcea parvifolia A. Nels.	smallflower globemallow
	Sphaeralcea sp. St.-Hil.	globemallow
Nyctaginaceae	*Mirabilis bigelovii* Gray	wishbone-bush
	Mirabilis decipiens (Standl.) Standl.	broadleaf four o'clock
	Mirabilis linearis (Pursh) Heimerl	narrowleaf four o'clock
	Mirabilis sp. L.	four o'clock
Oleaceae	*Forestiera pubescens* var. *pubescens* Nutt.	stretchberry
Onagraceae	*Gaura coccinea* Nutt. ex Pursh	scarlet beeblossom
	Oenothera sp. L.	evening-primrose
Pinaceae	*Pinus edulis* Engelm.	twoneedle pinyon
	Pinus ponderosa P. & C. Lawson	ponderosa pine
	Pseudotsuga menziesii (Mirbel) Franco	Douglas-fir
Plantaginaceae	*Plantago lanceolata* L.	narrowleaf plantain
	Plantago patagonica Jacq.	woolly plantain
Poaceae	*Agropyron desertorum* (Fisch. Ex Link) J.A. Schultes	desert wheatgrass
	Aristida divaricata Humb. & Bonpl. ex Willd.	poverty threeawn
	Aristida purpurea Nutt. var. *longiseta* (Steud.) Vasey	Fendler’s threeawn
	Aristida purpurea var. *fendleriana* (Steud.) Vasey	Fendler's threeawn
	Aristida sp. L.	threeawn
	Bouteloua curtipendula (Michx.) Torr.	sideoats grama
	Bouteloua eriopoda (Torr.) Torr.	black grama
	Bouteloua gracilis (Willd. ex Kunth) Lag. ex Griffiths	blue grama
	Bromus ciliatus L.	fringed brome
	Bromus rubens L.	red brome
	Bromus tectorum L.	cheatgrass
	Bromus sp. L.	brome
	Dactylis glomerata L.	orchardgrass
	Elymus elymoides ssp. *elymoides* (Raf.) Swezey	squirreltail

Family	Scientific Name	Common Name
	Elymus sp. L.	wildrye
	Eragrostis lehmanniana Nees	Lehmann lovegrass
	Festuca arizonica Vasey	Arizona fescue
	Monroa squarrosa (Nutt.) Torr.	false buffalograss
	Muhlenbergia montana (Nutt.) A.S. Hitchc.	mountain muhly
	Muhlenbergia rigens (Benth.) A.S. Hitchc.	deergrass
	Pascopyrun smithii (Rydb.) A. Love	western wheatgrass
	Poa fendleriana (Steud.) Vasey	muttongrass
	Poa secunda J. Presl	Sandberg bluegrass
	Schizachyrium scoparium ssp. *scoparium* (Michx.) Nash	little bluestem
	Sporobolus cryptandrus (Torr.) Gray	sand dropseed
	Sporobolus sp. Br.	alkali sacaton
Polemoniaceae	*Ipomopsis aggregata* ssp. *aggregata* (Pursh) V. Grant	scarlet gilia
	Ipomopsis arizonica (Greene) Wherry	Arizona ipomopsis
	Ipomopsis multiflora (Nutt.) V. Grant	manyflowered ipomopsis
Polygonaceae	*Eriogonum alatum* Torr.	winged buckwheat
	Eriogonum corymbosum var. *aureum* (M.E. Jones) Reveal	crispleaf buckwheat
	Eriogonum divaricatum Hook.	divergent buckwheat
	Eriogonum jamesii Benth.	James' buckwheat
	Eriogonum jonesii S. Stewart	Jones' buckwheat
	Eriogonum microthecum Nutt.	slender buckwheat
	Eriogonum racemosum Nutt.	redroot buckwheat
	Eriogonum umbellatum var. *cognatum* (Greene) Reveal	sulphur-flower buckwheat
	Eriogonum sp. Mitchx.	buckwheat
	Polygonum aviculare L.	prostrate knotweed
Polypodiaceae	*Cheilanthes feei* T. Moore	slender lipfern
Portulacaceae	*Portulaca oleracea* L.	little hogweed
Ranunculaceae	*Clematis lingusticifolia* Nutt.	western white clematis
	Thalictrum fendleri Engelm. ex Gray	Fendler's meadow-rue
Rosaceae	*Agrimonia gryposepala* Wallr.	tall hairy agrimony
	Amelanchier utahensis Koehne	Utah serviceberry
	Cercocarpus montanus Raf.	alderleaf mountain mahogany
	Chamaebatiaria millefolium (Torr.) Maxim	fernbush
	Fallugia paradoxa (D. Don) Endl. ex Torr.	Apache plume
	Petrophytum caespitosum (Nutt.) Rydb.	mat rockspirea
	Prunus virginiana L.	chokecherry
	Purshia mexicana (D. Don) Henrickson	Mexican cliffrose
	Purshia stansburiania (Torr) Henrickson	Stansbury cliffrose
	Rosa woodsii var. *ultramontana* (S. Wats.) Jepson	Woods' rose
Rubiaceae	*Galium stellatum* Kellogg	bedstraw
	Galium wrightii Gray	Wright's bedstraw
	Galium sp. L.	starry bedstraw
Rutaceae	*Ptelea trioliata* ssp. *angustifolia* (Benth.) V. Bailey	common hoptree
Salicaceae	*Salix laevigata* Bebb.	red willow
	Salix lasiolepis Benth.	arroyo willow
Saxifragaceae	*Heuchera parviflora* Bartl.	littleleaf alumroot

Family	Scientific Name	Common Name
	Heuchera rubescens var. *versicolor* (Greene) M.G. Stewart	pink alumroot
Scrophulariaceae	*Castilleja integra* Gray	wholeleaf Indian paintbrush
	Castilleja sp. Mutis ex L. f.	Indian paintbrush
	Linaria genistifolia (L.) P. Mill.	Dalmatian toadflax
	Penstemon barbatus (Cav.) Roth	beardlip penstemon
	Penstemon jamesii Benth.	James' beardtongue
	Penstemon linarioides Gray	toadflax penstemon
	Penstemon linarioides ssp. *compactifolius* Keck	toadflax beardtongue
	Penstemon rostriflorus Kellogg	Bridge penstemon
	Penstemon sp. Schmidel	penstemon
	Penstemon thompsoniae (Gray) Rydb.	Thompson's beardtongue
	Verbascum thapsus L.	common mullein
Solanaceae	*Datura wrightii* Regel	sacred thorn-apple
	Lycium pallidum Miers	pale desert-thorn
	Physalis hederifolia var. *fendleri* (Gray) Cronq.	Fendler's groundcherry
Valerianaceae	*Valeriana arizonica* Gray	Arizona valerian
	Valeriana edulis Nutt. ex Torr. & Gray	tobacco root
Verbenaceae	*Verbena bracteata* Lag. & Rodr.	bigbract verbena
Viscaceae	*Phoradendron juniperinum* Engelm.	juniper mistletoe
Vitacaceae	*Parthenocissus quinquefolia* (L.) Planch.	Virginia creeper
	Parthenocissus vitacea (Knerr) A.S. Hitchc.	woodbine
	Vitis arizonica Engelm.	canyon grape

APPENDIX G

G. Visual Guide and Descriptions of the Walnut Canyon National Monument Map classes

Introduction

This document is a guide to the photointerpretation of vegetation map classes for Walnut Canyon National Monument. Its purpose is to provide a ground photo image for each map class, provide visual examples of each map code with aerial photographs and delineated overlays, and provide descriptions for the visual examples.

This guide does not attempt to show all variations of each map class; only the most common or significant representations are included. The descriptions should be sufficient to give the user a feel for the imagery and an understanding of the relationships between the vegetation and the map classes.

How this Guide is Organized

This guide describes and illustrates every vegetation map class used in the Walnut Canyon vegetation mapping project. The format is one map class per page. The images are scanned aerial photographs with their Mylar overlays showing the photointerpreter's work and the map code in yellow. Ground photos of each type are included where available. The photos are accompanied by a brief description of the distribution of the map class within the project area and how it generally appeared on the aerial photos. Other information about the map class or the polygon may be included if it improved understanding or recognition of that particular map class.

The map classes are arranged in order of map code number. To find the information for a particular map class, use the index that follows this introduction to find the page number for that map code.

Aerial Photographs

Merrick, & Company of Aurora, Colorado flew the aerial photographs for WACA on October 8, 1996. The photos were taken at a flight altitude of 6,000 ft (1,829 m) above sea level using Kodak Aerochrome Infrared 2443 film. The photo mission was designed to take photos with about 30% side lap (between each flight line) and 60% overlap (along each flight line). The scale of the CIR 9 x 9-in photos is 1:12,000 (approximately 1 in = 1,000 ft, 1 cm = 102 m). Two sets of contact prints were produced and used for stereoscopic interpretation. A total of 44 frames taken over six flightlines covered the project area.

Color Infrared Film (CIR)

CIR film is best for highlighting subtle changes in deciduous and wetland vegetation. Evergreen vegetation can also be distinguished using CIR film, although not as clearly as deciduous trees and shrubs. CIR film presents a "false color" picture that combines infrared reflectance with green and red visible bands. These differences in reflectance create differences in tone and color that can be easily distinguished and delineated as different plant communities. Reflectance is influenced by structure of the canopy, the orientation of the plants and their leaves, and the thickness and pigment content of leaves.

Texture is also important to the photointerpreter. For trees, texture is influenced by type and orientation of leaves, crown size and shape, and branch structure. An uneven canopy will appear lumpy, an even canopy smooth. Similarly, trees having small crowns will appear a finer texture than trees that have large crowns. Depending on the tree species, the texture can be rough or smooth, fine, lacy, billowy, compact, or any number of other descriptors. These are imprecise terms, but nonetheless provide important visual cues to the imagery. In contrast, herbaceous vegetation, including wetland and upland communities, generally tend to lack texture (Hershey and Befort 1995).

CIR photography generally is not consistent enough to allow a species or type to be described precisely. Film batch, printing process, sun angle, light intensity, shadow, and exposure can all affect the appearance of CIR photography (Hershey and Befort 1995). For accurate mapping at WACA, ground verification by both the photointerpreter and the project ecologists was very important for successful interpretation of types with confusing or similar signatures.

Literature Cited:

Hershey, Rachel Riemann; Befort, William A. 1995. Aerial photo guide to New England forest cover types. General Technical Report NE-195. Radnor, PA: USDA, Forest Service, Northeastern Forest Experiment Station. 70 p.

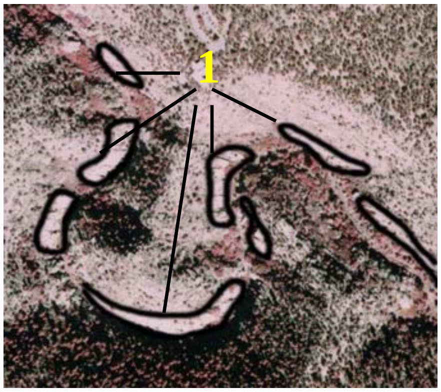
Alphabetical Index To the Vegetation Map Codes

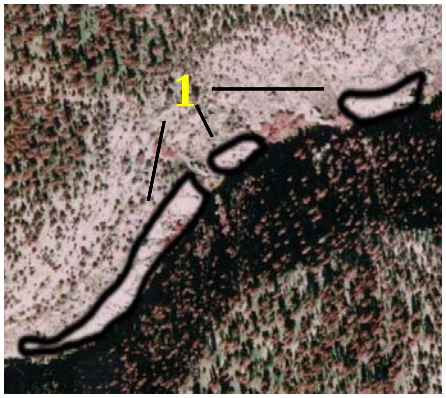
Alphabetical Index To the Anderson Land Use Map Codes

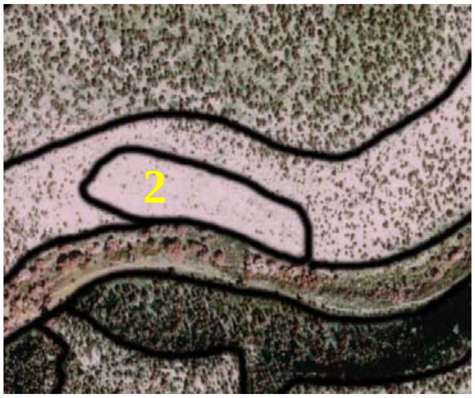
Sparsely Vegetated Coconino Sandstone (1) and Sparsely Vegetated Kaibab Limestone (2)

Location: Outcrops of Coconino sandstone and Kaibab limestone are exposed on the walls of Walnut Canyon. Kaibab limestone lies above the Coconino sandstone and appears higher on the canyon walls, while Coconino sandstone crops out only at the bottom of the canyon.

Photosignature: Both rock types appear white on the aerial photos and are distinguished primarily on the basis of relative position and texture. The ledgy stratigraphy of the limestone gives it a striated appearance in the photos, whereas the sandstone appears as narrow uniform bands.







Sparsely Vegetated Intermittent Drainage Channel (3)

Location: Floor of Walnut Canyon.

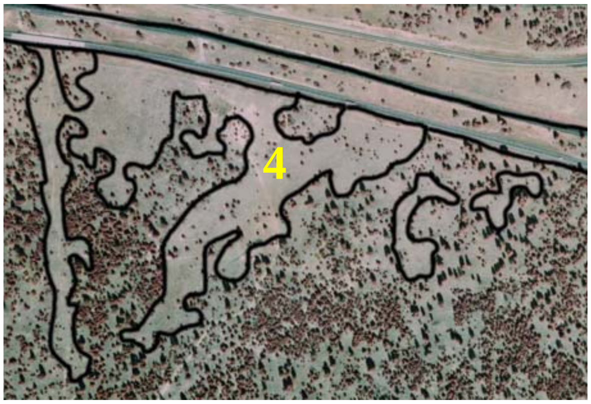
Photosignature: White due to unvegetated sands and gravels in the intermittent stream channel.

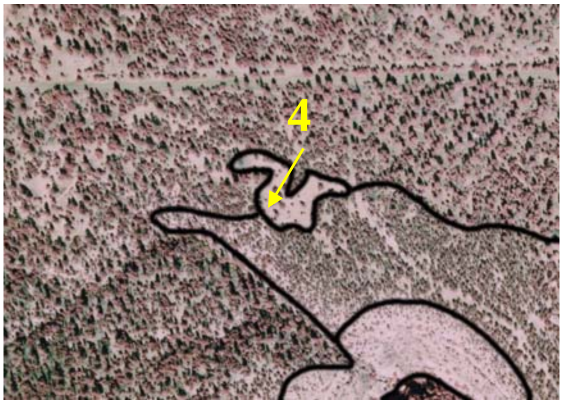
Figure: See figure on page G-21.

Blue Grama-Mountain Muhly Grassland Group (4)

Location: This mixed grassland occupies swales and openings among stands of ponderosa pine. Occurrences are scattered throughout the west half of the mapping area, both north and south of Walnut Canyon.

Photosignature: Smooth-textured, uniform pale green to whitish-gray. Small trees within the grasslands appear as dark red specks.

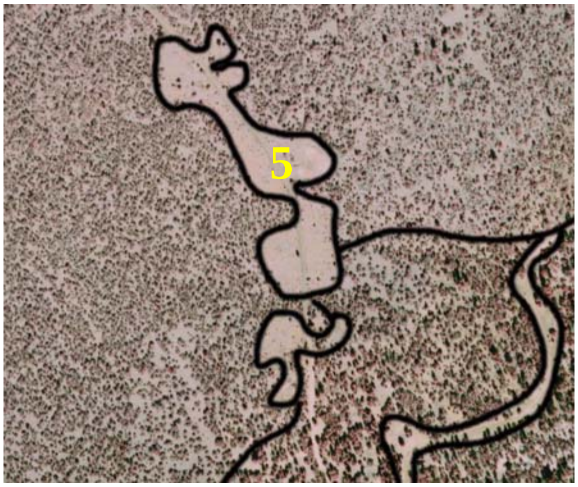




Introduced Western Wheatgrass Herbaceous Vegetation (5)

Location: This type occurs in clearings and meadows where it was planted following clear cutting or chaining of the original woodland vegetation. It was mapped on the basis of field observations.

Photosignature: Western wheatgrass meadows are gray to pale green and have an exceptionally smooth texture resulting from the rhizomatous growth form of the grass.

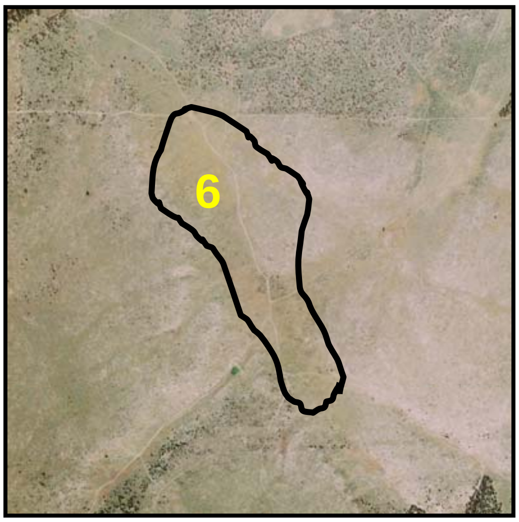


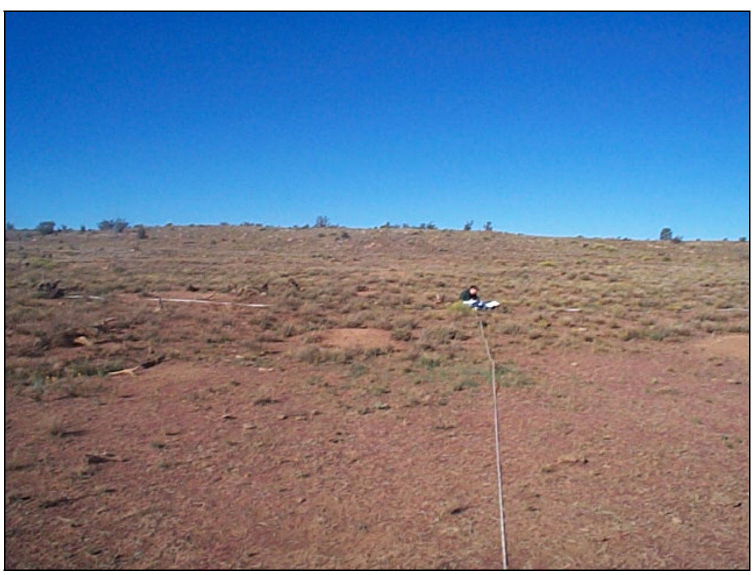
No ground photographs are available for this map class.

Common Horehound – Prairie Dog Town (6)

Location: This type is isolated to one relatively large polygon in the northeast quadrant of the project area. This map class is completely contained in the environs portion of the project.

Photosignature: This map unit is characterized by the disturbance created by prairie dog activity. Prairie dog impact is witnessed by the combination of the stippled, white holes representing their burrows and the smearing of yellow and orange colors resulting from the annual weedy vegetation growing on the site. The vegetation signature for this prairie dog town is caused by an abundance of common horehound.

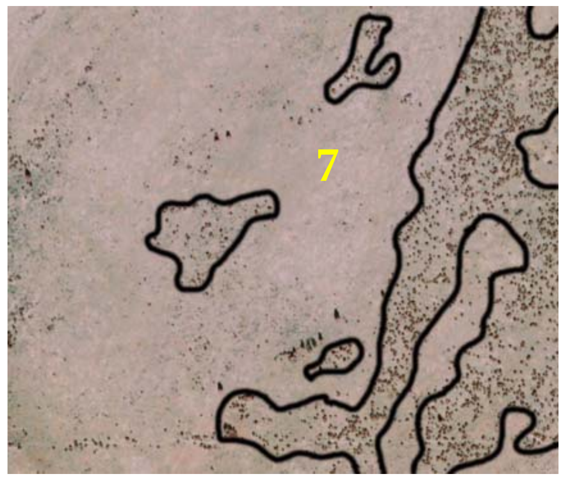




Snakeweed/Modified Grassland Complex (7)

Location: This type occurs in a large, nearly uninterrupted block in the northeastern part of the mapping area. It lies in an area between the Monument access road on the west, US Highway 40 on the north, and Walnut Canyon on the south and east.

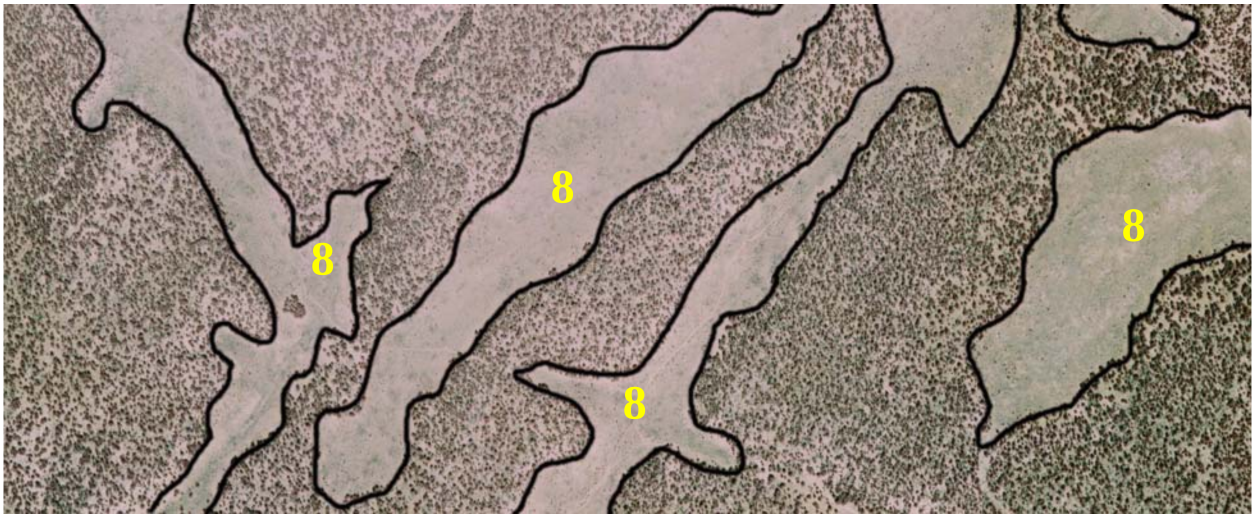
Photosignature: This type is an aggregation of several disturbed and introduced grassland and shrubland types, so the signature is varied throughout its extent. The basic color is pale gray-green to pale green, with patches of white, darker green and pink representing the different vegetation types. Small juniper and pinyon trees are scattered throughout the type and appear as brown to reddish specks. Occasionally, linear striations that represent lines of chaining or plowing and planting are apparent.



Rabbitbrush / Blue Grama Shrub Herbaceous Vegetation (8)

Location: Broad drainages and parks on the eastern side of the project area. The best examples are southeast of Walnut Canyon.

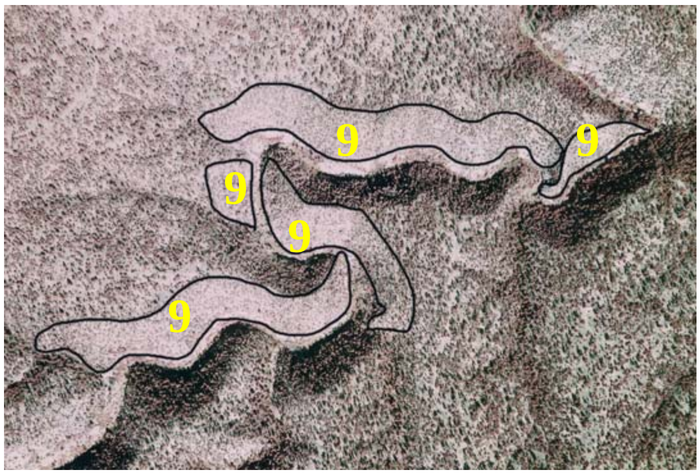
Photosignature: Predominantly smooth-textured and greenish-gray in color, although dense stands of rabbitbrush are indicated by a gritty texture.



Limestone Rim Complex (9)

Location: This complex of woodland, shrubland, and sparse plant associations occurs on south, east, and west-facing canyon slopes in Walnut Canyon. It also occurs on north-facing slopes in the lower part of Walnut Canyon where the canyon is wider and the walls are less steep.

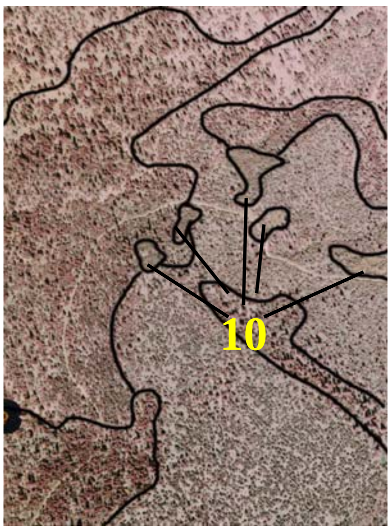
Photosignature: The basic color of the signature is white, modified by the type of vegetation present. Sparse vegetation tints the signature slightly gray to light green with a mottled texture. Denser shrublands and areas where pinyon pines and junipers grow are more speckled in appearance; the speckles are gray and brownish green.

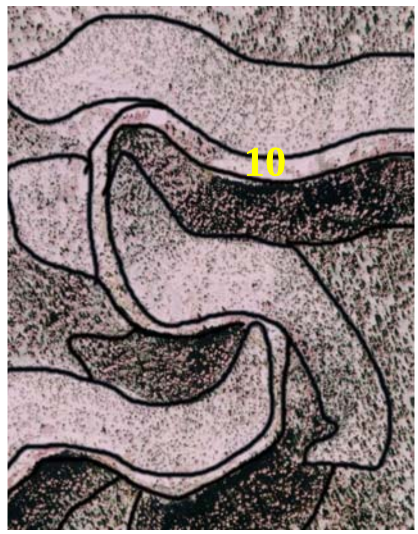


Canyon Floor Complex (10)

Location: This mosaic of deciduous types occupies the bottom of Walnut and Cherry Canyons on terraces above the former active channel. A few stands also occur in sheltered upland areas south of Walnut Canyon.

Photosignature: Because this map class includes several plant associations, the signature is a complicated one. Gambel oak stands have an even, pebbly texture and are dark red to orange red in color. Box elder and cottonwood trees tend to occur in smaller clumps or as scattered individuals, and the crowns are generally a brighter red. Clones of shrubs such as snowberry, chokecherry and wild privet appear as smoother red patches. The deciduous woodlands and shrublands are separated by an area of mixed forblands and grasslands, which appear pale gray on the photos.

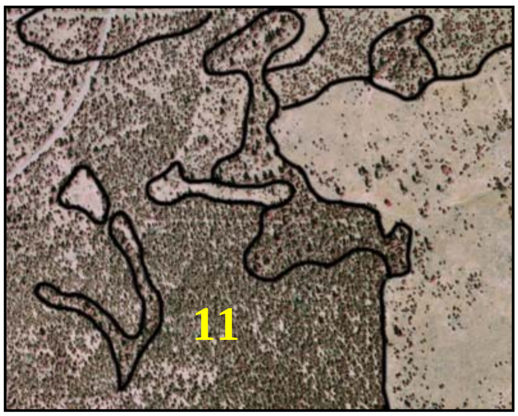


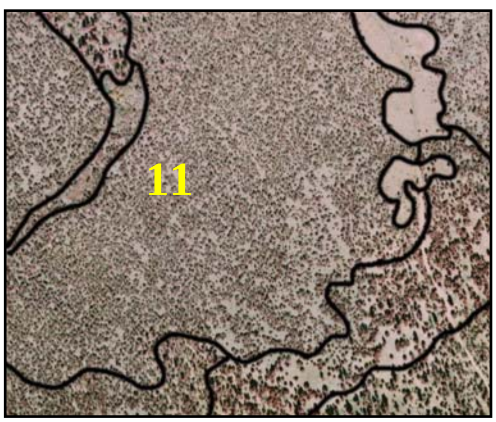


Pinyon Pine - Utah Juniper / Blue Grama Woodland (11)

Location: This type occupies large areas throughout the mapping area. It occurs east of the Monument access road, north of the canyon, and south of the canyon on a basalt covered slope of Anderson Mesa.

Photosignature: The older stands (mostly south of the canyon) have an evenly pebbly texture resulting from the even spacing of tree crowns. North of the canyon in the disturbed area the trees are in mixed aged stands with an uneven pebbly appearance. In both cases the tree crowns are grayish brown tinged with red.





Ponderosa Pine - Pinyon Pine - Juniper / Blue Grama Woodland (12)

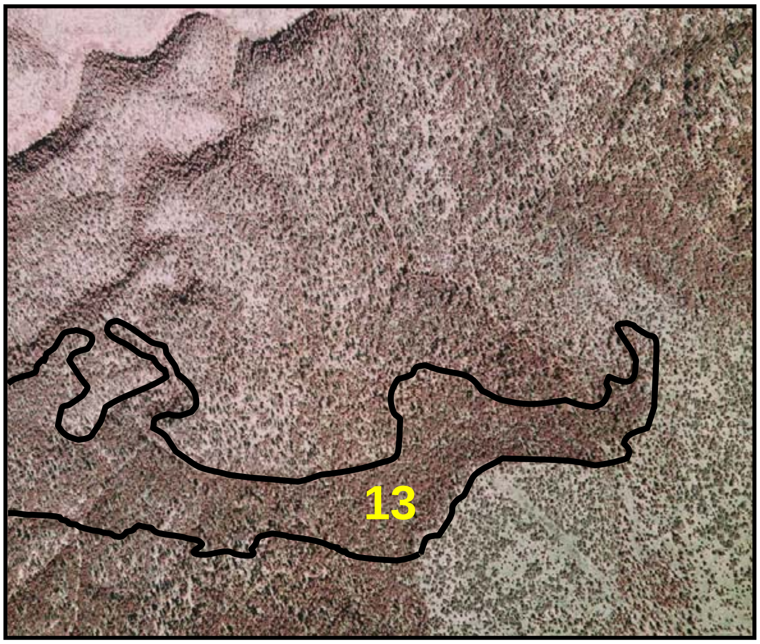
Location: This map unit is widespread throughout the mapping area and is abundant on the west side of the project area, decreasing gradually to the east. This type occurs on primarily uplands both north and south of Walnut Canyon.

Photosignature: Ponderosa pines appear as red specks, while pinyon and juniper trees appear as brown specks. Taller ponderosas have black shadows. The stands are generally open, so the overall appearance is that of coarse sandpaper; red and brown specks in a pale gray matrix. The complete absence or dramatic reduction of Gambel oak stands (appearing as brick red clumps) distinguishes this type from Map Unit 13.

Ponderosa Pine - Pinyon Pine - Juniper / Gambel Oak Woodland (13)

Location: This map unit is located primarily south of Walnut Canyon in the southwest corner of the project area. A few pockets of this type also occur along the western project boundary. This type is very similar to Map Class 12 but has a larger component of Gambel oak.

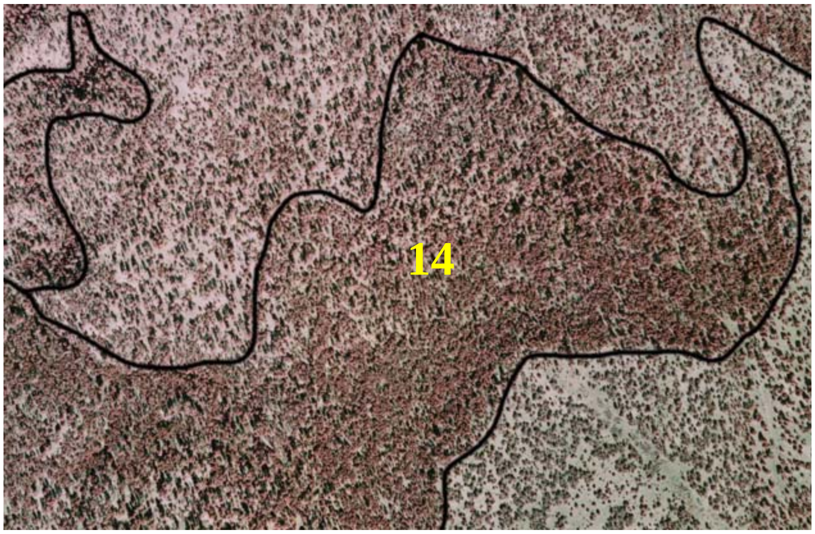
Photosignature: The photosignature for this type is similar to Map Unit 12 with the ponderosa pines appearing as red specks, pinyon and juniper trees as brown specks, and the taller ponderosas having black shadows. However, this type is usually significantly denser with dark, brick red clumps of Gambel oak filling the understory space. This results in a loss of the blue-green background color typical of Map Unit 12. Map Unit 13 also differs from Map Unit 15, Ponderosa Pine / Gambel Oak Woodland, by the presence of pinyon and juniper trees.



Ponderosa Pine / Gambel Oak Woodland (14)

Location: This type occurs primarily south of Walnut Canyon and from just east of Cherry Canyon, west to the project area boundary.

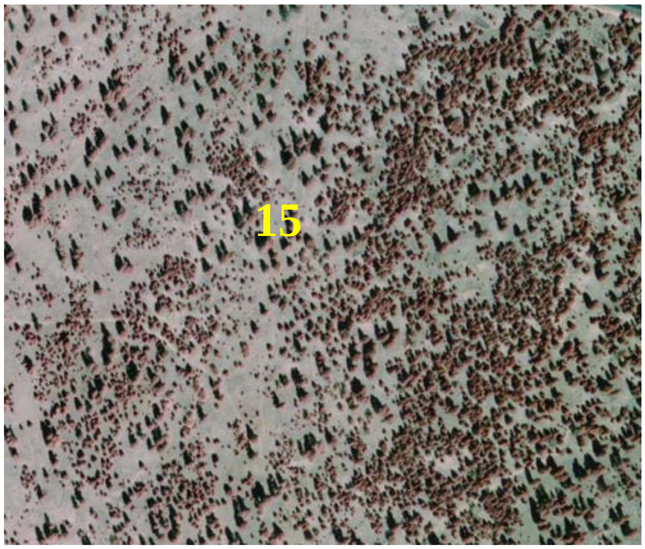
Photosignature: The signature is very similar to that of Map Code 16, but the crowns of Gambel oak trees/shrubs are visible as red-gold to dark-red, rough-textured specks and patches among the dark-red ponderosa pine crowns.



Ponderosa Pine Mixed Graminoid Woodland Complex (15)

Location: This type is best developed north of Walnut Canyon and west of the Monument access road. Smaller examples of this type also occur on the west side of the project area south of the canyon.

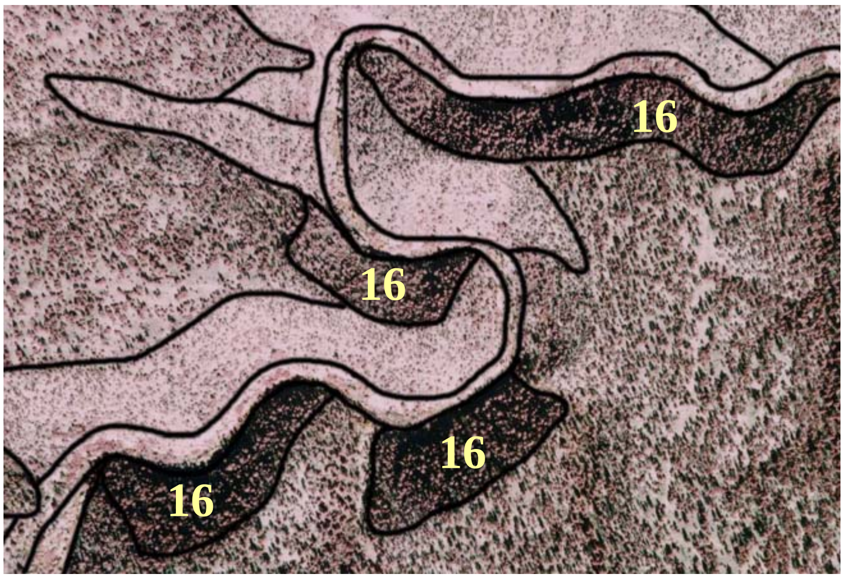
Photosignature: The texture is uneven, with pines of all sizes occurring in open to dense stands. Taller pines have black shadows, and all pines have red crowns. The grassy openings among the trees are gray green to pale green in color and have a smooth texture.



Douglas-fir / Gambel Oak Forest (16)

Location: This forest type occurs on north-facing canyon walls below the rim of Walnut Canyon.

Photosignature: Douglas-fir forests are uneven and rough in texture, and dark brown tinged with red in color.



Rural Residential (17)

Location: West and north edges of the project area.

Photosignature: Rectangular shapes for houses, landscaping, and outbuildings. Roofs, lawns, access roads, etc. appear in a variety of colors.

Figure: On page G-21.

Ranch Developments (18)

Location: Isolated buildings and corrals on private lands, often near pastures (22).

Photosignature: Similar to rural residential (17).

Figure: On page G-21.

NPS Facilities (19)

Location: Monument facilities, located at the end of the main park road. Includes buildings, a water tower and sewage treatment ponds.

Photosignature: Individual structures are easily identifiable. The fact that they are park facilities was confirmed in the field.

Figure: On page G-21.

Utility Corridors (20)

Location: A telephone line cuts east-west through the central part of the project area.

Photosignature: This type was field verified. It consists of a narrow belt of smooth, gray-green color.

Figure: On page G-21.

Transportation Routes (21)

Location: Transportation roads, including improved county roads and unimproved tracks, occur throughout the project area.

Photosignature: White for gravel and dirt roads, black for paved roads. Texture is smooth for all roads.

Figure: On opposite page.

Pastures (22)

Location: North center edge and the west edge of the mapping area, on private lands.

Photosignature: Smooth-textured, light grayish-green for dormant grasslands. Straight edges indicate fence lines or the boundary of pasture plantings.

Figure: On opposite page.

Reservoirs (23)

Location: The historic reservoir site on private land in the bottom of Walnut Canyon.

Photosignature: Whitish-gray reflecting bare ground; smooth gray texture indicating annual herbaceous vegetation. The dam structure is evident.

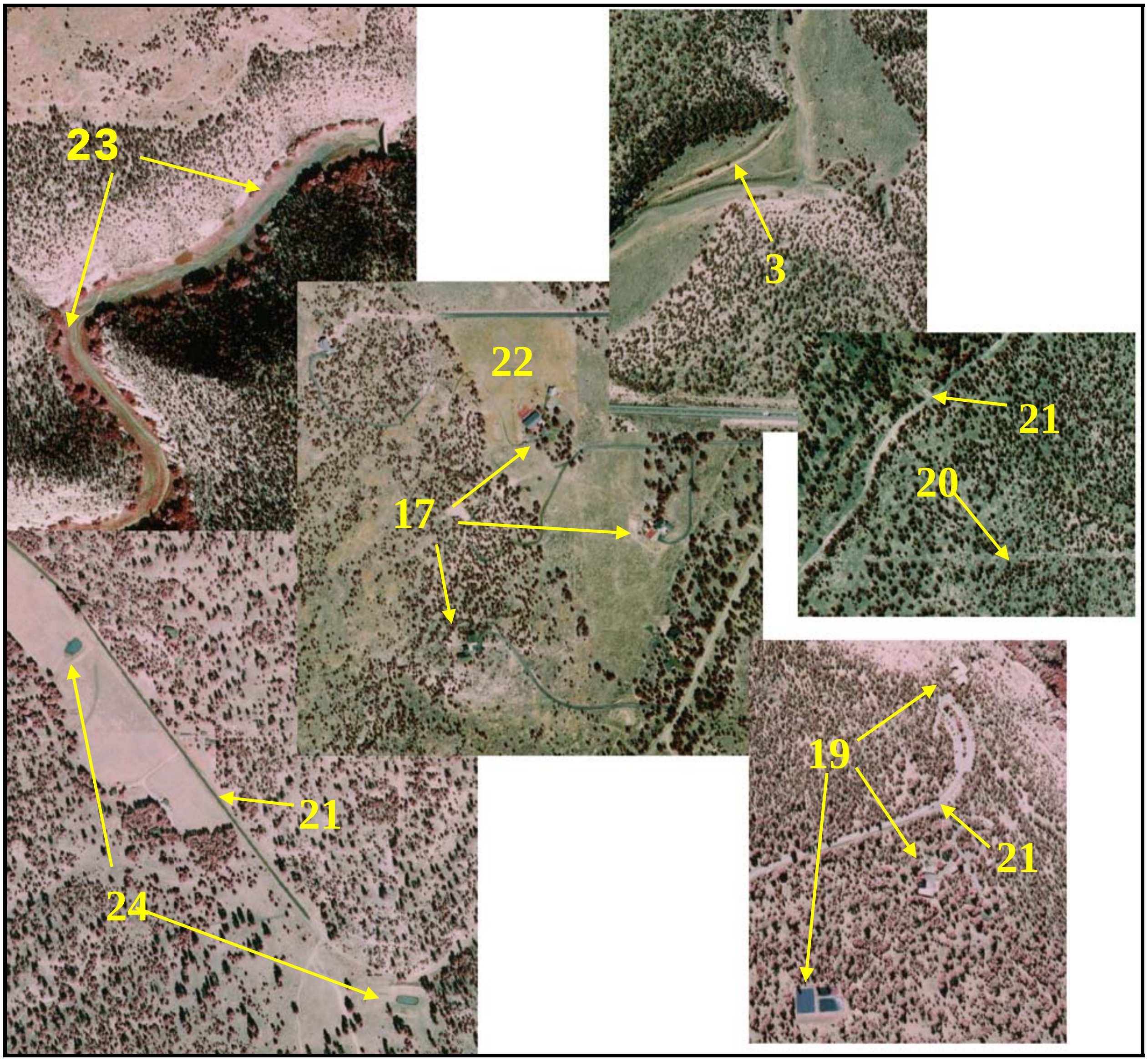
Figure: On opposite page.

Stock Tanks and Dams (24)

Location: Scattered throughout the project area outside the Monument boundary.

Photosignature: Usually a dark blue-green spot surrounded by a curved shape in white, gray or orange, depending on the color of the substrate the tank was dug in.

Figure: On opposite page.



Examples of aerial photosignatures for Anderson Land Use map classes at Walnut Canyon as they appear on the aerial photographs. Map code numbers are in yellow.